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Waste Minimization Audit Report Case Studies of Minimization of Solvent Wastes and Electroplating Wastes at a DOD (Department of Defense) Installation

Versar, Inc., Springfield, VA

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The report results of a waste minimization audit carried out in 1987 at a tank reconditioning facility operated by the DOD. The audit team developed recommendations for reducing the generation F006 wastewater treatment sludge, and F002, and F004 solvent wastes. In addition to detailing recommendations for the subject streams the report outlines the US EPA recommended procedure for conducting waste minimization audits.

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WASTE MINIMIZATION AUDIT REPORT

Case Studies of Minimization of Solvent Wastes and Electroplating Wastes at a DOD Installation

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Foreword

The term, "waste minimization," is heard increasingly at meetings and conferences of individuals working in the field of hazardous waste management. Waste minimization is an umbrella term that includes the first four categories of the EPA's preferred hazardous waste management strategy which is shown below:

1. Waste Reduction: Reduce the amount of waste at the source, through changes in industrial processes.

2. Waste Separation and Concentration: Isolate wastes from mixtures in which they occur.

3. Waste Exchange: Transfer wastes through clearinghouses so that they can be recycled in industrial processes.

4. Energy/Material Recovery: Reuse and recycle wastes for the original or some other purpose, such as for materials recovery or energy production.

5. Incineration/Treatment: Destroy, detoxify, and neutralize wastes into less harmful substances.

6. Secure Land Disposal: Deposit wastes on land using volume reduction, encapsulation, leachate containment, monitoring, and controlled air and surface/subsurface water releases.

In general, the idea underlying the promotion of waste minimization is that it makes far more sense for a generator not to produce waste rather than develop extensive treatment schemes to insure that the waste stream poses no threat to the quality of the environment.

In carrying out its program to encourage the adoption of waste minimization, the Hazardous Waste Engineering Research Laboratory has supported a program to carry out waste minimization audits in a wide variety of industrial settings. This report contains the results of several such audits carried out to reduce the generation of cadmium/cyanide and solvent wastes. It will be useful to individuals interested in identifying opportunities for reducing those waste streams.

For further information, please contact the Alternative Technologies Division of the Hazardous Waste Engineering Research Laboratory.

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ABSTRACT

The U.S. Environmental Protection Agency is encouraging hazardous waste generators to develop programs to reduce the generation of hazardous waste. To foster such programs, the Agency's Office of Research and Development Hazardous Waste Engineering Research Laboratory (ORD/HWERL) is supporting the development and evaluation of a model hazardous waste minimization audit (WMA) procedure using the EPA hierarchy of waste minimization (WM) options, with source reduction being more desirable and recycle/reuse less desirable. Treatment options, although not considered WM, were evaluated if neither of the former alternatives was available. The WMA procedure was tested initially in several facilities in 1986. WMAs were conducted at generators of a number of generic hazardous wastes, including corrosives, heavy metals, spent solvents, and cyanides.

In 1987, the HWERL WMA program has concentrated on ORD's top priority RCRA K and F waste list. Audits were conducted at generators of K071 and K106 wastes (mercury cell chloralkali plants), K048-K052 wastes (sludges and solids from petroleum refining), F002-F004 wastes (spent solvents), and F006 wastes (wastewater treatment sludges from electroplating operations). The present report covers a WMA carried out at a DOD installation responsible for the rehabilitation of worn Army tanks. This audit was aimed at developing WM options for F002, F004, and F006 listed wastes.

Two source reduction options were developed by the audit team for F002 and F004 wastes with attractive payback periods and substantial potential savings in waste solvent disposal costs. A number of source reduction and recycle/reuse options were developed for the electroplating wastes which, if successfully implemented, could result in substantial savings in F006 waste disposal costs as well as achieve compliance with the DOD installation's NPDES permit limitations for cadmium and cyanide.

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SECTION 1

INTRODUCTION

The national policy objectives established under the 1984 Hazardous and Solid Waste Amendments to the Resource Conservation and Recovery Act of 1976 include the goal of reducing or eliminating hazardous waste as expeditiously as possible. To promote waste minimization activities, the Hazardous Waste Engineering Research Laboratory (HWERL) of the U.S. Environmental Protection Agency (EPA), Office of Research and Development, has undertaken a project to develop and test a waste minimization audit (WMA) procedure. It is envisioned that such a procedure would be useful to generators of hazardous waste as they search for waste minimization alternatives.

A number of authors have recognized the potential value and desirability of conducting waste audits, although they have suggested differing approaches and scope limits for such audit activities (U.S. Congress 1986, USEPA 1986a, Fromm and Callahan 1986, Pojasek 1986, Kahane 1986, League of Women Voters, Mass. 1986). This HWERL project expands on a recently developed and tested audit procedure (EPA 1987, EPA 1987a, EPA 1987b) by conducting actual WMAs in cooperating industrial and government facilities. The present project includes an audit at a DOD installation, and is one of several current audit efforts being supported by HWERL.

Section 2 of this report presents the elements of an overall waste minimization program, of which the audit procedure is an important component. Section 3 describes the WMA procedure, its development, and its final recommended form. Section 4 presents the results of a WMA performed at a DOD installation with a facility that generates listed waste F006. Section 5 contains the results of a WMA performed at the same installation with a facility that generates listed wastes F002 and F004. Conclusions and recommendations resulting from these audits are presented in the respective sections.

SECTION 2

WASTE MINIMIZATION PROGRAM

Structured programs designed to improve the cost, energy efficiency, safety, and other environmental aspects of an industrial undertaking are not a new concept. During World War II, the General Electric Corporation developed standardized procurement procedures for reducing product cost without sacrificing functionality. Later, similar procedures were developed and applied to lower the costs of design and construction projects. This activity, known as value management, value engineering, or value analysis, is currently a well established government requirement. In fact, it was mandated by the U.S. EPA for all construction projects involving wastewater treatment plants. A subsequent study of 156 treatment plants showed that cost reduction programs saved $95 million, or a 12 to 1 return on investment (Zimmerman and Hart 1982).

Environmental compliance audits and reviews are also becoming more common and are acquiring the status of an industry norm. The primary objective of an environmental audit is to determine the status of a corporation's compliance with Federal, State, and local environmental laws and regulations (Truitt et al. 1983). Additionally, such audits often can provide information to aid risk assessment and corporate planning.

Energy conservation audits are performed to reduce energy consumption per unit production. It was estimated that energy audits helped save chemical process industries about $1 billion between 1974 and 1979 (Parkinson 1979). Other related structured programs include safety reviews, hazard analyses, or failure mode and effects analyses. Waste minimization programs can be considered to be in the same category as these programs.

The principal objective of a waste minimization (WM) program is to reduce the quantity and/or toxicity of waste effluents leaving the production process in a manner consistent with the goals of protecting human health and environment. Unlike environmental audit programs, a WM

program does not seek to determine or improve the regulatory compliance status of a facility. Rather, it is primarily oriented toward producing a set of effective measures to reduce waste generation.

Table 1 presents a breakdown of WM program elements. In the context of an overall WM program, the waste auditing process (composed of pre-audit, audit, and post-audit phases) follows the program initiation/planning phase. During this initiation/planning phase, the commitment of top management to reduce waste generation must first be established. This is often done with a formal directive signed by the chief executive officer of the firm or an administrator of a government organization. The organizational commitment to start a WM program is often associated with a goal setting process, e.g., duPont is currently implementing an annual 5 percent waste reduction goal.

A corporate WM program may be organized in a typical pyramid structure, with command and monitoring functions centered at the corporate level and implementation responsibility totally delegated to individual plants. A corporate-level independent expert task force may be formed to assist individual plants in setting up and executing their own WM programs.

At the plant level, the WM program may follow the scheme successfully used at Union Carbide for energy conservation efforts. At Union Carbide plants, a plant program coordinator is appointed and supported by a committee. The coordinator then selects and oversees individuals in each department who are responsible for devising and/or carrying out WM activities in their departments (Williams 1976).

This program planning phase should include the selection of audit teams to carry out the next program phase. The audit team leader should have a strong technical background, demonstrated problem solving ability, and, if possible, experience associated with the relevant process(es). In addition, the leader should possess strong management and communication skills. It would be preferable for the leader, or at least some members of the audit team, to have no previous association with the plant, so as to bring a fresh and unbiased perspective to the audit process. Such outsiders can be independent consultants or qualified personnel from other plants.

The audit team must have access to all required documentation and to a wide variety of plant personnel. During a recent internal workshop on waste minimization conducted by a major U.S. corporation, the participants (mostly environmental affairs managers at individual plants) were asked who should provide support to a waste audit team. The following responses were obtained:

Table 1. Waste Minimization Program Elements

Program phase	Job plan* phase	Elements
I. Initiation/ Planning		• Secure commitment/authority • Establish goals • Establish organization
II. Pre-Audit	Information	• Preparation for the audit • Pre-audit inspection • Waste stream selection
III. Audit	Creative	• Facility inspection • Generate comprehensive set of WM options
	Judgment	• Options evaluation • Selection of options for feasibility analysis
IV. Post-Audit	Development	• Technical and economic feasibility analysis
	Recommendation	• Report preparation
V. Implementation		• Selection of options for implementation • Design, procurement, construction • Startup • Performance monitoring

* Term adopted from value management program.

- Raw material suppliers;
- QA/QC department;
- Outside consultants;
- Customer representatives;
- Process engineer;
- Safety engineer;
- Materials engineer;
- Foreman;
- Plant manager; and
- Purchasing agent.

In short, the organization should be prepared to provide the audit team with access to a wide range of people both inside and outside the firm. The teams that carried out the audits described in this report were composed entirely of employees from outside consulting/engineering firms. Table 2 depicts the composition of the outside audit teams and the resident support groups.

The waste minimization auditing process (Table 1, phases II, III, and IV), which is described in detail in the next section, provides the key input to the implementation phase of the program, i.e., recommendations on which WM measures are to be implemented. Once a decision is made to proceed with the implementation of a specific WM measure, subsequent activities follow a well established, conventional pattern. Detailed design follows preliminary design; the procurement effort proceeds from inquiry and definitive bids to bid analysis and the expediting stages; and construction advances along the path determined by a detailed schedule and budget. The budget is controlled through estimates of cost performed at various project stages; accuracy increases as material and labor requirements become better defined. Startup follows mechanical completion. Finally, to ascertain the effectiveness of the changes made, ongoing performance monitoring is undertaken.

Table 2. Waste Audit Teams and Resident Support Groups for the Audits at a DOD Installation Generating Listed Wastes F006, F002, and F004

1. Outside Audit Team

   Chemical engineer*, Ph.D., 37 yrs of experience, audit team leader

   Chemical engineer, B.S., 4 yrs of experience

   Independent consultant*, 45 yrs of experience in the metal finishing industry

2. Resident Support Team

   Plant environmental engineer

   Plant process engineer

   Facility supervisors

   U.S. Army Pentagon Environmental Office engineers

* Technical support and review function only.

SECTION 3

WASTE AUDITING METHODOLOGY

As was shown in Table 1, waste minimization audits are a central feature of a WM program. The auditing process is subdivided into pre-audit, audit, and post-audit phases. The recommended sequence of steps shown in Table 1 (also shown in expanded form in Table 4), is based on modifications of the originally proposed sequence, which is presented in Table 3. Modifications were made to reflect the experience and insights gained as a result of actual audit work. The following sections detail each of the eight sequential steps of the recommended waste minimization audit (WMA) procedure shown in Table 4.

PREPARATION FOR THE AUDIT

The objective of this activity is to gain background information about the facility to be audited. Preparation should include examination of literature references related to the activities performed at the facility, such as EPA background documents on the industries involved, plant permit applications, and other relevant documents pertaining to waste discharge at the industrial facilities of interest. Proper preparation should result in a well-defined needs list, inspection agenda, or a checklist detailing what is to be accomplished, what questions or issues need to be resolved, and what information should be gathered.

For the host site audited in this report, the needs list (Table 5) was provided to the resident support team in advance of the site visit. This was very important in ensuring the success (and efficiency) of the site visit, since it provided time for the facility personnel to assemble the materials required by the audit team prior to its visit. A more generalized list of documents and information sources is given in Table 6.

In the audits of the facilities reported herein, the availability of the required process documentation was excellent. This documentation proved to be invaluable in enabling the audit team to establish a set of waste minimization options.

Table 3. Initially Proposed Waste Minimization Audit Procedure

Job plan element	Step
Information phase	1. Preparation for inspection
	2. Facility inspection
	3. Process and waste stream description
Creative phase	4. Generation of WM options
Judgment phase	5. Preliminary evaluation and ranking of options
	6. Presentation, discussion, and joint review of options with plant personnel
	7. Selection of options for feasibility analysis
Development phase	8. Technical and economic feasibility analysis
Recommendation phase	9. Final report preparation

Table 4. Recommended Waste Minimization Audit Procedure

Program phase	Activities	Product
Pre-Audit	1. Preparation for the audit	• needs list/ inspection agenda
	2. Pre-audit meeting and inspection	• notes
	3. Waste stream selection	• process description
		• waste descripton with rationale for selection
Audit	4. Audit inspection	• notes
	5. Generation of a comprehensive set of WM options	• list of proposed options with written rationale
	6. Options evaluation and selection for feasibility analysis	• list of selected options
		• options ratings by audit team and by plant personnel
		• options interim report
Post-Audit	7. Technical and economic feasibility analysis	• study or budget grade estimates of capital and operating costs; profitability analysis
	8. Final report preparation	• final report with recommendations

Table 5. Waste Minimization Audits - Information Needs List for Listed Wastes F006, F002 and F004 at a DOD Installation

1. Process Flow Diagrams (PFDs) with Heat and Material Balances (HMBs)
2. Piping and Instrumentation Diagrams (P&IDs)
3. Plot plan or general arrangement of equipment
4. Process description (process flows, liquid and solid wastes characterizations)
5. Equipment layouts (plan and elevation views)
6. Quantities and costs of chemicals
7. Dimensions and operating gallonage of all pertinent process vessels and tankage
8. Quantities and costs of disposal for all wastes (liquid and solid)
9. Process equipment materials of construction
10. History of previous waste management projects and any related documentation

Table 6. Waste Minimization Audits Generalized List of Information Sources

- Design process flow diagrams (PFD) with heat and material balances (HMB) for process and pollution control systems
- Equipment list
- Piping and instrument diagrams (P&ID)
- Materials application diagrams (MAD)
- Plot and elevation plans
- General arrangement drawings
- Piping layout drawings
- Operation manuals, process descriptions
- Permits and/or permit applications
- Emission inventories
- Hazardous waste manifests
- Annual (or biennial) reports
- Waste assays
- Operator data logs, batch sheets
- Materials purchase orders
- Environmental audit/review reports
- Production schedules
- Organization chart

Experience with other sites indicates that the availability and quality of information varies significantly, however. It is important to allow for this contingency and to have a fall-back position. For example, if a piping and instrument diagram (P&ID) is not available, it may be possible to obtain a piping layout plan instead. Similarly, if the information cannot be obtained from the facility, that does not mean that it is unavailable elsewhere. Much information is obtainable from outside vendors, e.g., the costs of bath make-up chemicals or the physical design of the process equipment. If information is truly needed, it can be obtained with proper initiative and ingenuity, although such action may affect project costs and schedules. In light of this possibility, it is important to seek only that information which is necessary to understand the process, to allow for delineation of waste sources and current waste management techniques, and to characterize waste generation quantitatively. Requesting unnecessary information burdens both the provider and user (auditor) and slows down the work.

HOST SITE PRE-AUDIT VISIT

The purpose of this meeting is to become familiar with plant operations and plant personnel. Initial contacts with plant personnel should include solicitation of their views on the focus and function of the audit. This will help to identify waste streams of concern to the facility. The information needs defined in the previous step should be discussed here and hopefully met. A guided tour of the facility should be taken.

At this initial visit, the groundwork for a successful working relationship with facility personnel must be laid. It should be stressed that a cooperative attitude and active involvement by host facility personnel are essential to the success of the audit process. The initial point of contact at the facility (Plant Manager, Environmental Coordinator, etc.) must be enlisted as a "Product Champion" for the program before the audit commences. He/she must be encouraged to relay the message of cooperation and involvement to others at the facility.

WASTE STREAM SELECTION

Suitable waste streams should be selected either following the initial conference with plant personnel or after the first plant inspection. Selection should be based on discussions with plant personnel and on the independent assessment of the project team. The criteria used to select a waste stream must include at a minimum:

- Composition;
- Quantity;

- Degree of hazard (toxicity, flammability, corrosivity, and reactivity);
- Method and cost of disposal;
- Potential for minimization and recycle; and
- Compliance status.

For the two case studies cited in this report, stream selection was not a problem. Focusing the audits on three particular wastes (listed wastes F002, F004, and F006) simplified the selection. These are the principal hazardous wastes generated at the audited DOD installation.

With the selection of the waste streams, the pre-audit stage of the procedure is completed. At this point, it is recommended that a written description be prepared of the facility, process (or operation) and of the waste streams. The description should encompass:

- Facility location and size;

- Description of operations or processes of concern, including diagrams necessary to detail the pertinent aspects of waste generation; and

- Waste stream(s) description centering on sources and current methods of management; this information should be supplemented with summaries of generation rates, compositions, disposal costs, and raw material costs, and the rationale for waste selection should be provided.

Descriptions of facility, process, and waste stream(s) for the facilities involved with audits on listed waste F006 are given in Section 4. Section 5 presents this information as related to listed wastes F002 and F004. Such descriptions summarize all the pertinent information acquired.

HOST SITE WASTE MINIMIZATION AUDIT VISIT

In the course of the pre-audit activities, a general understanding of the process facility operations and, more important, of waste sources was established. Also, waste stream selection had been finalized (in most cases) and the information summarized in a written description of the facility, process, and waste stream(s).

With the needed comprehension of the process and focus in place, the audit inspection can now be conducted. Typically, the inspection would focus on selected aspects of the operation identified through the pre-audit activities. The governing objective is to obtain a greater awareness of the principal and secondary causes of waste generation and to examine the items overlooked in the pre-audit stage.

The audit inspection is the ultimate step in the information gathering process. The following guidelines have been formulated as a result of the work performed on this project:

1. Have an agenda ready. This should cover all points that still require clarification following the pre-audit phase.

2. Plan on inspection of the various process operations of interest at different times during the production shift for continuous processes, in order to observe possible fluctuations in normally steady-state operations. Expect to monitor operations over a period of 1 to 2 days.

3. Obtain permission to interview the operators, 8-hour shift supervisors, and foremen directly. Listen attentively and do not hesitate to question more than one person if the answer is not forthcoming. Try to assess the operators' and their supervisors' awareness of waste generation aspects of the operation. Note their familiarity (or the lack thereof) with the impacts their operation may have on other operations, e.g., the effect of dumping solvent spills into the existing wastewater treatment plant, rather than metering these solutions at a controlled rate.

4. Obtain permission to photograph the facility. Photographs are especially valuable in the absence of plan layout drawings. Many details can be captured in photographs that otherwise could well be forgotten or inaccurately recalled at a later date.

5. Observe the "housekeeping" aspect of the operation. Check for signs of spills or leaks. Ask to visit the maintenance shop and inquire about their problems in maintaining the equipment leak-free. Assess the overall cleanliness and order of the site.

6. Assess the level of coordination of environmental activities among various departments.

During the planning stage and the actual audit inspection itself, it is beneficial to mentally "walk the line" from the suspected source of waste generation to the point of exit, be it a treatment unit, storage facility, or haulage to offsite RCRA treatment, storage, and disposal (TSD) facilities. The audit inspection must result in a clear understanding of the causes of waste generation.

GENERATION OF WM OPTIONS

Thus far, the audit process has been mainly oriented toward information gathering and organization. These activities should have yielded a thorough understanding of the origins of waste generation and of the process or facility operations in general. The audit activity has now reached the creative phase.

The objective of this step is to generate a comprehensive set of WM options. Such activity may take the form of a "brainstorming" session involving audit team members or may involve separate efforts by individual members. A combination of these approaches was found to be of value during the audits conducted for this study. In this stage of the audit process, it is important to generate as many options as possible. Current WM measures in the audited facility should also be listed. This knowledge often leads to the formulation of additional options and provides valuable insights for the option evaluation step to follow.

In generating options, most of the effort should first focus on source reduction, followed by recycling and then treatment (if there are no options available in either of the preferred areas). Such a hierarchy of effort stems from the fact that environmental desirability favors source reduction over recycling and recycling over treatment.

Current EPA-proposed definitions of waste minimization and key waste minimization terms are given in Figure 1. A generalized guide map to various source reduction elements is shown in Figure 2. For a discussion of the terms and examples illustrating each element, the reader is referred to the EPA support document for the 1986 Report to Congress on Waste Minimization (USEPA 1986b).

To develop options, it is often necessary to examine the technical literature. The reference section of this report lists the sources consulted for technical material relevant to reduction or elimination of solvent and cyanide electroplating wastes. Options can also be formulated through discussion with manufacturers of equipment or suppliers of process input materials.

The result of the WM options generation step should be a list identifying each option, together with a brief description of the rationale for its listing. For the F006 waste studied in this report, a total of seven relevant options could be determined at the facility audited, while for the F002 and F004 wastes, a total of four relevant options were developed at this facility.

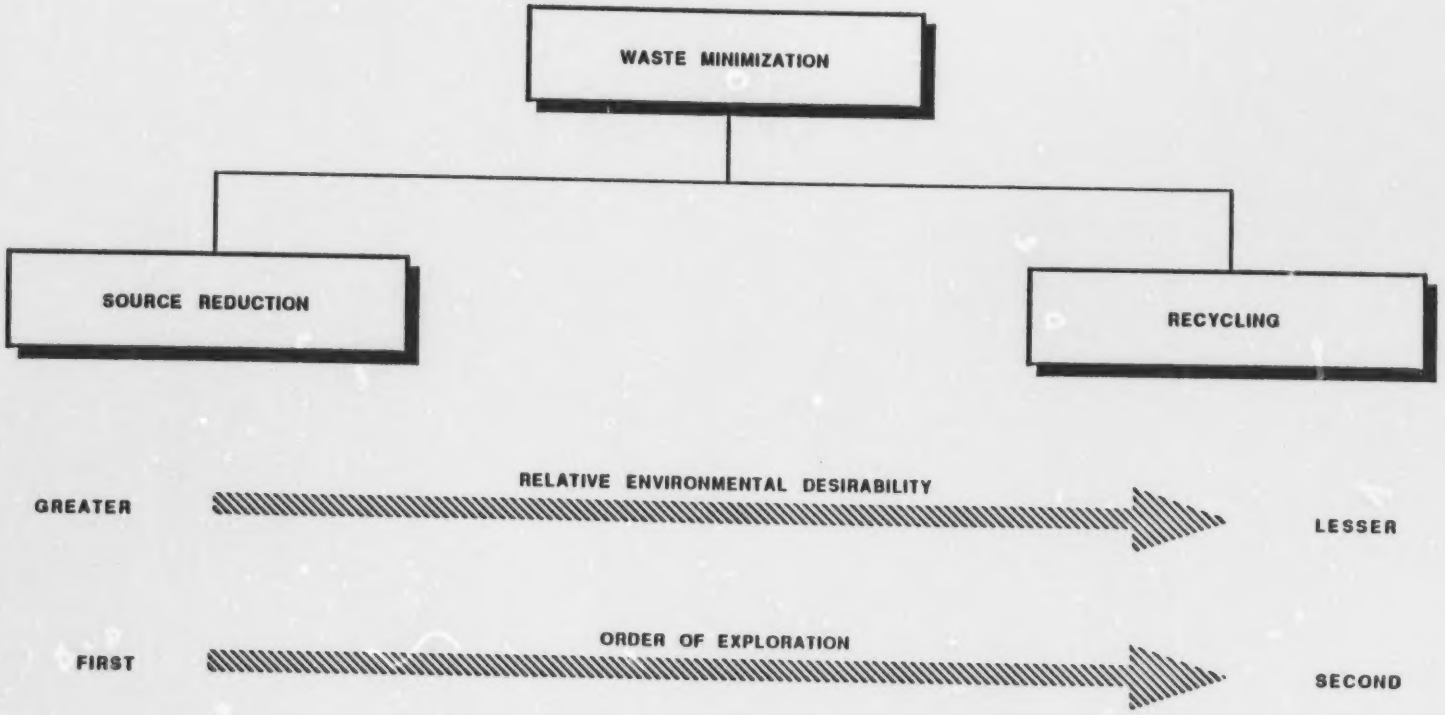

FIGURE 1. COMPONENTS OF WASTE MINIMIZATION, THEIR HIERARCHY AND DEFINITIONS

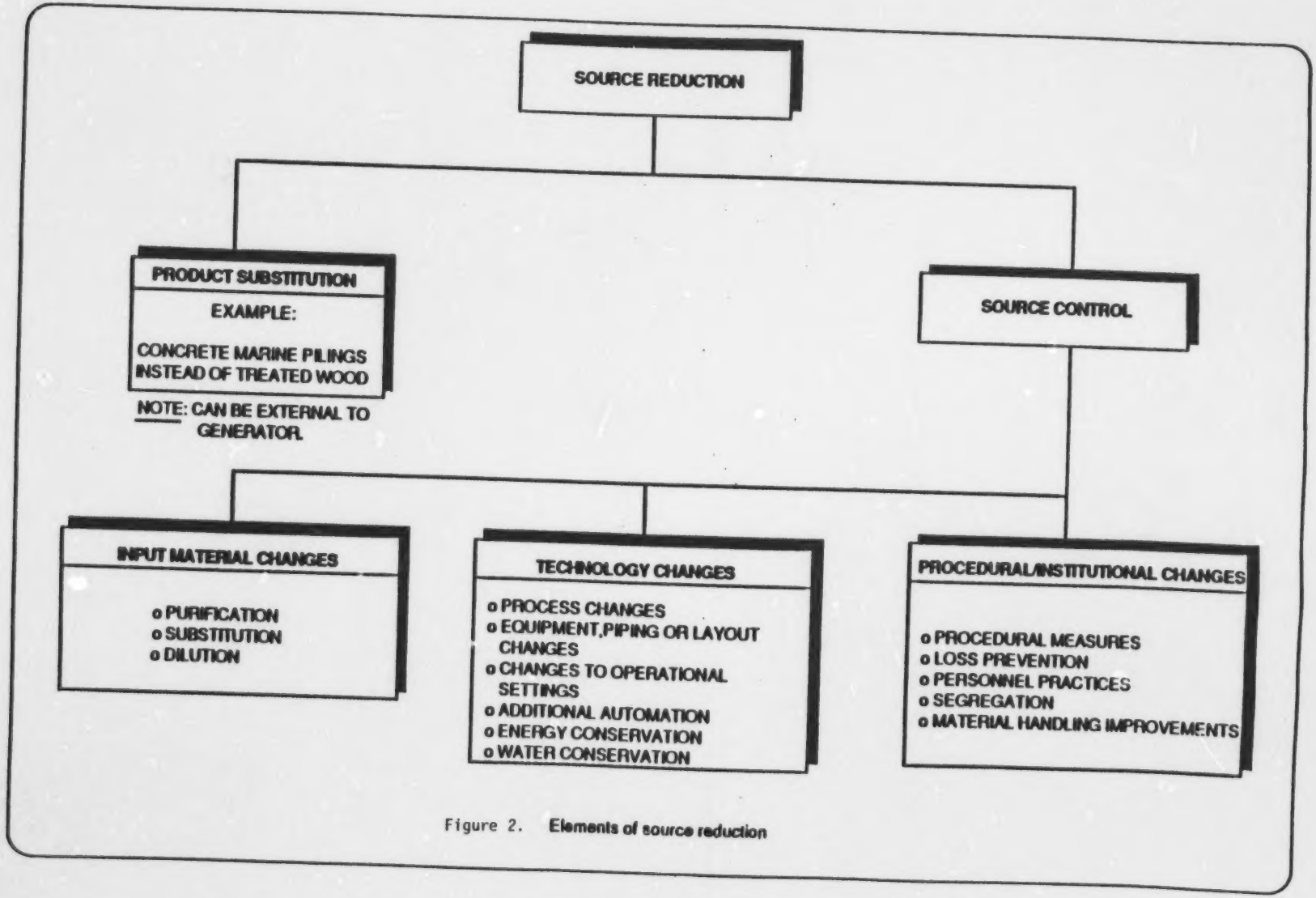

Figure 2. Elements of source reduction

PRELIMINARY EVALUATION AND RATING OF OPTIONS

Each of the options postulated in the preceding step must undergo a preliminary engineering evaluation and rating. The objective of this evaluation is to eliminate the measures that do not merit additional consideration and to rank the remaining measures in order relative to their overall desirability.

The evaluation should include, at a minimum, consideration of the following aspects:

- Waste reduction effectiveness (i.e., reduction of waste quantity and/or toxicity);
- Extent of current use in the facility;
- Industrial precedent;
- Technical soundness;
- Cost (preliminary capital and operating cost evaluation). An important economic yardstick for option evaluation is the determination of a "payback period," which is defined here as the incremental investment divided by the net savings in direct operating costs resulting from implementation of the proposed option.
- Effect on product quality;
- Effect on plant operations;
- Implementation period; and
- Resources availability and requirement.

The preliminary evaluation and valuing process would consist of the following steps carried out by the audit team:

(a) Developing a written rationale for each proposed option including a clear description of the operating principle, estimates of waste minimization measured in pounds of waste and in pounds of waste per unit production, estimates of potential resource recovery measured in pounds of waste component recyclable to the process or salable as a recovered material, perceived advantages and disadvantages, simplified schematics of the proposed material flow, material balance calculations, "order of magnitude" cost estimates, references relating to prior applications, and other relevant documentation pertaining to the idea. These steps were carried out as appropriate for each option developed for minimization of listed wastes F006, F002, and F004

(b) Qualitative rating of each option in three categories: waste reduction effectiveness, extent of current use, and future application potential. The ratings are to be done on scale of 0 to 10 by a proponent, then reviewed by the audit team leader.

It is expected that some options may receive ratings low enough to warrant their withdrawal. The team leader may call a review meeting to submit the ratings to a collective discussion or vote. In the case of the audits discussed in this report, a number of such options were withdrawn, as is discussed in Sections 4 and 5.

The product of this effort should be a table summarizing the preliminary ratings for each option that addresses a particular waste stream or source, along with the written documentation developed in this phase of the audit. Table 7 is a sample table illustrating the approach used to develop such a summary table.

PRESENTATION AND JOINT REVIEW OF OPTIONS WITH PLANT PERSONNEL

Following the technical and economic evaluations of the selected options by the audit team, these options are prepared in the form of a Preliminary Audit Report to be submitted to appropriate plant personnel. Each option in the Preliminary Audit Report should be well described in terms of the technical rationale and projected "order of magnitude" cost estimates. Cost estimates are of particular importance to plant personnel who have to deal with tight operating budgets and must have some idea of the cost of implementing an attractive-appearing option. In this regard, calculation of "the payback period" will provide a quick indication of the economic viability of the proposed option. Cost estimates are also of importance to the options belonging to the category of good operating practices. Availability of preliminary cost data along with the presentation of this category of option circumvents quick dismissal of these options as "trivial" by a technology-oriented plant engineer.

The plant personnel should then be asked to review the Preliminary Audit Report and independently rate each proposed option, revise them based on their assessment, and incorporate any additional options they consider applicable.

The review process would culminate in a joint meeting in which the audit team would present the proposed options one by one. The presentation ideally should include a detailed discussion of the rationale and reasons for selected ratings. The plant engineers would then present their critique or comments. The discussion should conclude with a revised rating acceptable to both sides. If such a conclusion cannot be reached, a further course of action must be well outlined.

Table 7. Summary of Source Control Methodology for the A/B Powder Formulation Process: Illustration of Development of Options Ranking

Waste source	Control methodology	Waste reduction effectiveness	Extent of current use	Future application potential	Fraction of total waste	Current reduction index	Future reduction index
Weighing operation	1. Return empty containers	2	0	2		0.00	0.25
	2. Use preweighed containers	2	0	4		0.00	0.50
	3. Use drum covers	2	2	1		0.25	0.06
	Overall	2.00	0.67	2.33	0.10	0.25	0.50
Wet grind loading and unloading	1. Use plastic funnel/collar on unit	2	0	4		0.00	0.50
	2. Use smaller trays, manual operation	2	0	2		0.00	0.25
	3. Place trays on rack, walk-in oven	2	0	2		0.00	0.25
	4. Use elevator table on rack, walk-in oven	1	0	1		0.00	0.06
	5. Install roller conveyer under valve	1	0	1		0.00	0.06
	6. Install fail-close valve on discharge	2	0	3		0.00	0.38
	7. Pump slurry into trays over at oven	2	0	1		0.00	0.13
	8. Reduce cleaning frequency	3	0	3		0.00	0.56
	9. Bypass dry grinding unit	2	0	4		0.00	0.50
	Overall	1.89	0.00	2.33	0.45	0.00	0.56
Dry grind loading and unloading	1. Use plastic funnel/collar on unit	2	0	4		0.00	0.50
	2. Do not load while unit is operating	3	4	0		0.75	0.00
	3. Inspect all seals regularly	2	3	2		0.38	0.06
	4. Use drum covers	2	2	3		0.25	0.19
	5. Bypass dry grinding unit	4	0	4		0.00	0.90
	Overall	2.60	1.80	2.60	0.45	0.75	0.90
All sources	All methods				1.00	0.58	0.71

The objective of the meeting is to obtain an agreement on the ratings of various proposed options; these ratings would then be analyzed and used to rank all the options, with the aim of selecting those that warrant further evaluation by the plant. It also may happen that the plant personnel may suggest new options or that such options may result from the joint discussion.

Following the meeting, all appropriate revisions of the options presented in the Preliminary Audit Report would be made in preparation for the issuance of a Final Audit Report.

In the present audit effort, both the audit team and the plant personnel were in agreement on the evaluation of each of the options presented.

FINAL AUDIT REPORT

In accordance with the workplan, the Final Audit Report will contain, at a minimum, the following sections:

1. Facility and process description;
2. Description of waste stream(s) origin, composition, and quantities;
3. Detailed description of all work minimization options considered, including simplified schematics of revised process flows (if appropriate) and lists of any new process equipment required;
4. Detailed evaluation of technical feasibility and potential benefits of all waste minimization options considered, together with their preliminary economics (capital and operating costs, estimated payback period) and final rankings (based on audit team findings and host plant engineers evaluations); and
5. Recommendations including any research and development efforts needed to further evaluate the recommended options.

WASTE AUDITING - SOME DO'S AND DON'TS

Some of the most important lessons learned in the pilot audits relate to the human element of the audit process, i.e., to the interaction between the audit team and the host facility personnel.

Obviously it is vital that host facility personnel become and remain active participants throughout the audit process. Some nontechnical skills of the audit team personnel, and particularly of the audit team leader, were found to be extremely valuable here.

The audit team leader must be an effective and aggressive communicator as well as a technical expert, because this individual must serve as a facilitator for the audit team and host facility personnel alike. A reserved and low key attitude and behavioral style by the audit team could lead to a passive or disinterested stance by the host facility personnel.

The experience gained in these audits also led to a modification of the audit method. The modified approach requires host facility personnel to independently develop ratings for each of the waste reduction options under consideration. The audit team's ratings for the options and the host facility's independent ratings can then be reviewed and reconciled in a group session. The initial approach of having the host facility personnel merely review and discuss the audit team's ratings following the presentation of the option ratings resulted in relatively casual, uninvolved behavior by the host facility staff.

The pre-audit activities, particularly the pre-audit site visits, were found to be extremely important in facilitating the audit process. When the audit team spent a little more time getting to know the host facility staff and the functioning of the organization, the audit process moved more smoothly. The audit team found it easier and faster to acquire needed data, because the members knew the operation and the people a little better, and the level of cooperation by plant staff was improved.

In summary, a WMA (and a WM program as a whole) requires that audit team members exhibit effective communications and human interaction skills, as well as technical insight and engineering ability. A successful WM audit program thus requires success in both technical and human relations areas.

SECTION 4

LISTED WASTE F006 - WMA CASE STUDY

The focus of this case study is to propose ways to reduce or eliminate the generation of listed waste F006. Generalized information on the source and composition of this waste is available in the RCRA listing background document (USEPA 1980). This waste is defined in 40 CFR 261.32 as follows:

> F006: Wastewater treatment sludges from electroplating operations. These sludges include cadmium and chromium hydroxides precipitated in the central wastewater treatment facility at the site.

A DOD installation that includes an electroplating facility generating plating waste, was chosen as the host site.

FACILITY DESCRIPTION

The DOD installation, located in Eastern Alabama, is a major military equipment servicing unit involved, among other activities, in the rehabilitation of Army tanks and repair of small arms. The waste minimization audit activities presented in this study are directed toward these areas of the installation's activities.

With respect to tank overhaul and maintenance at the DOD installation, the Army's M48s, M60s, M551s, and the new M1 Abrams tanks are completely disassembled in the appropriate shops. Reusable parts and those items that can be reclaimed are sent to satellite shops throughout the area where they are stripped of rust, oil, and paint. As required, various parts are plated, remachined, and surface coatings applied to meet applicable specifications. The parts are then returned to the assembly lines where they are used in rebuilding the tank hulls and turrets. Assembled tanks are then tested and shipped.

With respect to small arms repair, weapons that have been classified as "unserviceable" are sent to the DOD installation where they are repaired. Like the tanks, the small arms are dismantled and faulty components are replaced or repaired. The weapons parts are then metal-finished, reassembled, and function test-fired to ensure they meet quality standards prior to shipment.

Cadmium/cyanide and chromium-bearing wastes are generated in plating operations at the installation's plating shop (Building 114).[1] At the time of the WMA at Building 114, approximately 2,000 gallons per day of cyanide-bearing waste were being generated and sent to the wastewater treatment facility for treatment. This represents a considerable decline in waste output (normal output is in the 7,000 to 10,000 gallons per day range depending on plating shop production rate). About 35,000 gallons per day of chromium-bearing wastewaters are sent to the wastewater treatment facility. Normally, cadmium/cyanide or chromium plating baths are discharged.

The combined wastewater treatment sludge (including the F006 waste generated from treatment of cadmium/cyanide and chromium plating wastewaters) from the industrial waste treatment facility (IWTF) averages about 40,000 lb/wk and is sent offsite to a hazardous waste landfill.

EQUIPMENT LAYOUT DESCRIPTION

All electroplating operations at the DOD installation are carried out in Building 114. These include cadmium/cyanide plating, chromium plating, and all related operations (phosphatizing, stripping, bright dipping, degreasing, rinsing, anodizing, etc.). The dimensions and operating specifications of the major equipment in the cadmium/cyanide plating lines (including an automatic plating line using barrels to carry the parts and a manually-operated rack line) are listed in Tables 8 and 9, respectively. Similar information for the manually operated chromium plating line is shown in Tables 10 and 11, respectively.

All cadmium and chromium plating solutions are continuous filtered in below-grade (basement level) filtration units. In order to enhance the effectiveness of the hot rinsing operations, these rinse tanks are equipped with air sparging devices. Agitation in plating and stripping tanks is done either through pumparound circulation or air sparging.

During operations, overflow from the cadmium plating rinse tanks is routed to a cadmium/cyanide sump, and then pumped to an alkaline chlorination system for cyanide destruction (Building 506) prior to being sent to the onsite Industrial Wastewater Treatment Plant (IWTP), as described below. Overflow from the chromium plating rinse tanks is also routed to the IWTP for treatment (as described below). Makeup water to the rinse tanks is controlled by conductivity probes in these tanks.

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1 A small amount of intermittent nickel plating is also carried out at this facility.

Table 8. Dimensions, Construction, and Capacity of Major Cadmium/Cyanide Electroplating Line Equipment - Building 114[1]

Vessel No.[2]	Units	Operation	Size	Operating capacity (gallons)	Vessel construction
Cadmium/cyanide manual rack-plating line					
1	1	HCl pickling	4'x3'x6'	450	Mild steel, plastic-lined
2	1	Running rinse	4'x3'x6'	495	Mild steel, unlined
3	1	Reverse current	4'x3'x6'	450	Mild steel, unlined
4	1	Cold rinse	4'x3'x6'	495	Mild steel, unlined
5	4	Cadmium plating	4'x3'x6'	450	Mild steel, unlined
5	4	Cadmium plating	16'x3'x6'	1,800	Mild steel, unlined
6	2	Still rinse tank	4'x3'x6'	450	Mild steel, unlined
7	1	Cold rinse	4'x3'x6'	495	Mild steel, unlined
8	1	Hot rinse	4'x3'x6'	495	Mild steel, unlined
9	2	Dichromate oxidizing bath	4'x3'x6'	450	Stainless steel, unlined
10	1	Still rinse	4'x3'x6'	495	Mild steel, unlined
11	1	Hot rinse	4'x3'x6'	495	Mild steel, unlined
12	1	Drying oven	Front-loaded adjustable shelf	-	Mild steel

Table 8. (Continued)

Vessel No.[2]	Units	Operation	Size	Operating capacity (gallons)	Vessel construction
Cadmium/cyanide automatic barrel plating line					
1	1	Reverse current electrocleaning	32"x45"x28"	150	Mild steel, unlined
2	1	Cold rinse	32"x45"x28"	150	Mild steel, unlined
3	1	HCl pickling	32"x45"x28"	150	Polypropylene
4	1	Cold rinse	32"x45"x28"	150	Polypropylene
5	1	Blower for drying workpieces	-	-	-
6	1	Cadmium plating		1,100	Mild steel, plastic lined
7	1	Still rinse	32"x45"x28"	150	Mild steel, unlined
8	1	Cold rinse	32"x45"x28"	150	Mild steel, unlined
9	1	Dichromate oxidizing bath	32"x45"x28"	150	Polypropylene
10	1	Still rinse	32"x45"x28"	150	Polypropylene
11	1	Hot rinse	32"x45"x28'	150	Stainless steel
12	1	Blower for drying workpieces	-	-	-

[1] Source: DOD installation in-house data.

[2] Vessel numbers shown are arbitrary numbers used to identify the processing units and do not correspond to the actual site numbering system.

Table 9. Operating Specifications of Major Cadmium/Cyanide Electroplating Line Equipment - Building 114[1]

Vessel No.[2]	Operation	Operating temperature °C (°F)	Chemicals used	Heating method	Agitation method
Cadmium/cyanide manual rack plating line					
1	HCl pickling	Ambient	13% HCl	-	-
2	Running rinse	Ambient	Running water rinse; water addition controlled by conductivity measurement	-	-
3	Reverse current	Ambient	Non-cyanide alkaline cleaning solution	-	-
4	Cold rinse	Ambient	Cold water rinse; water addition controlled by conductivity measurement	-	-
5	Cadmium plating	21 (70)	18 oz/gal NaCN, 2.5-3.5 oz/gal Cd metal, 6-8 oz/gal Na_2CO_3	Electric immersion heaters	Pumped circulation with continuous filtration
5	Cadmium plating	21 (70)	18 oz/gal NaCN, 2/5-3.5 oz/gal Cd metal, 6-8 oz/gal Na_2CO_3	Electric immersion heaters	Pumped circulation with continuous filtration
6	Still rinse tank	Ambient	Ambient water rinse	-	-
7	Cold rinse	Ambient	Cold water rinse; water addition controlled by conductivity measurement	-	-
8	Hot rinse	82 (180)	Hot water rinse; water addition controlled by conductivity measurement	Steam heated coils	Air sparging

Table 9. (Continued)

Vessel No.[2]	Operation	Operating temperature °C (°F)	Chemicals used	Heating method	Agitation method
Cadmium/cyanide manual rack plating line					
9	Dichromate oxidizing bath	93 (200)	0.03 oz/gal sodium dichromate, 0.03 oz/gal phosphoric acid	Steam heated coils, insulated	-
10	Still rinse	Ambient	Cold water rinse; water addition controlled by conductivity measurement	-	-
11	Hot rinse	82 (180)	Hot water rinse; water addition controlled by conductivity measurement	Steam heated coils	Air sparging
12	Drying oven	93-260 (200-500)	-	Electric heat	
Cadmium/cyanide automatic barrel plating line					
1	Reverse current electrocleaning	Ambient	Non-cyanide alkaline cleaning solution	-	-
2	Cold rinse	Ambient	Cold water rinse; water addition controlled by conductivity measurement	-	-
3	HCl pickling	Ambient	13% HCl	-	-
4	Cold rinse	Ambient	Cold water rinse; water addition controlled by conductivity measurement	-	-

Table 9. (Continued)

Vessel No.[2]	Operation	Operating temperature °C (°F)	Chemicals used	Heating method	Agitation method
Cadmium/cyanide automatic barrel plating line					
5	Blower for drying workpieces	93-160 (200-500)	-	-	-
5	Cadmium plating	21 (70)	18 oz/gal NaCN, 2.5-3.5 oz/gal Cd metal, 6-8 oz/gal Na_2CO_3	Electric immersion heaters	Pumped circulation with continuous filtration
6	Still rinse	Ambient	Cold water rinse	-	-
7	Cold rinse	Ambient	Cold water rinse; water addition controlled by conductivity measurement	-	-
8	Dichromate oxidizing bath	93 (200)	0.03 oz/gal sodium dichromate, 0.03 oz/gal phosphoric acid	Steam heated coils, insulated	Air sparging
9	Still rinse	Ambient	Cold water rinse; water addition controlled by conductivity measurement	-	-
10	Hot rinse	82 (180)	Hot water rinse; water addition controlled by conductivity measurement	Steam heated coils	Air sparging
11	Blower for drying workpieces	-	-	-	-

[1] Source: DOD installation in-house data.

[2] Vessel numbers shown are arbitrary numbers used to identify the processing units and do not correspond to the actual site numbering system.

Table 10. Dimensions, Construction, and Capacity of the Major Chromium Electroplating Line Equipment - Building 114[1]

Vessel No.[2]	Units	Operation	Size	Operating capacity (gallons)	Vessel construction
Chromium plating line (manual or rack line)					
1	1	Chromium stripping bath (if required for old chromium plate)	6'x4'x8'	1,260 (operating level about 7 feet)	Mild steel, lead-lined
2	1	Preheat wax tank (preparation for coating of part areas not to be chrome plated)	6'x4'x3'		Mild steel, unlined
3	1	Wax dipping to cover part areas not be to be chrome plated	6'x3'x3'	340 (operating level about 2.5 feet)	Mild steel, unlined
4	1	Chromic acid etch	3'x3'x3'	140 (operating level about 2 feet)	Mild steel, lead-lined
5	2	Chromium plating	8'x2.5'x8'	1,050 (operating level about 7 feet)	Mild steel, lead-lined
6	6	Chromium plating	16'x2.5'x6'	1,500 (operating level about 5 feet)	Mild steel, lead-lined
7	6	Cold water rinse	4'x4'x6'	160	Mild steel
8	1	De-wax cabinet (for removal of coating from parts previously coated in areas not chrome plated)		Sufficient capacity to remove wax from 600 lb of parts per hour	Mild steel

[1] Source: DOD installation in-house data.

[2] Vessel numbers shown are arbitrary numbers used to identify the processing units and do not correspond to the actual site numbering system.

Table 11. Operating Specifications of Major Chromium Electroplating Line Equipment - Building 114[1]

Vessel No.[2]	Operation	Operating temperature °C (°F)	Chemicals used	Heating method	Agitation method
Chromium plating line (manual or rack line)					
1	Chromium stripping bath (if required for old chromium plate)	60 (140)	Sulfuric and chromic acids, 10 oz/gal each	Steam heated with titanium coils	PVC sparger for air agitation
2	Preheat wax tank (preparation for coating of part areas not to be chrome plated)	(120)	-	Steam heated	-
3	Wax dipping to cover part areas not to be chrome plated	49 (180)	Petroleum wax	Steam heated	-
4	Chromic acid etch	Ambient	Chromic acid (33 oz/gal), sulfuric acid (0.03 oz/gal)	-	-
5	Chromium plating	60 (140)	Chromic acid (33 oz/gal), sulfuric acid (0.33 oz/gal)	Steam heated with titanium coils	PVC sparger for air agitation
6	Chromium plating	60 (140)	Chromic acid (33 oz/gal), sulfuric acid (0.33 oz/gal)	Steam heated with titanium coils	PVC sparger for air agitation

Table 11. (Continued)

Operating Specifications of Major Chromium Electroplating Line Equipment - Building 114[1]

Vessel No.[2]	Operation	Operating temperature °C (°F)	Chemicals used	Heating method	Agitation method
Chromium plating line (manual or rack line)					
7	Cold water rinse	Ambient	Cold water rinse, water addition controlled by conductivity measurement	-	-
8	De-wax cabinet (for removal of coating from parts previously coated in areas not chrome plated)	Heated to melt wax off parts	-	Steam heated	-

[1] Source: DOD installation in-house data.

[2] Vessel numbers shown are arbitrary numbers used to identify the processing units and do not correspond to the actual site numbering system.

PROCESS DESCRIPTION

Cadmium/Cyanide Plating

The only source of cadmium/cyanide waste at Building 114 comes from rinse waters from selected cleaning operations and the dragout from cadmium plating operations. Two cadmium plating operations are in use: an automatic cadmium-cyanide plating line using barrels to hold the work pieces, and a manually operated cadmium-cyanide plating line using racks to hold the workpieces. Barrels are used for plating smaller parts, such as nuts and bolts, that do not lend themselves to being rack mounted.

The automatic line is the most heavily used of the cadmium plating lines. This line was being used on a continuous basis for one shift a day at the time of the audit. The line has been used up to three shifts per day in the past. Barrel-plating can generate significant amounts of cyanide waste because of the high level of dragout often associated with barrel-plating.

Figure 3 represents a simplified schematic of the automatic cadmium-cyanide plating operation at Building 114. Based on discussions with plant personnel, details of the automatic cadmium plating operations are as follows:

- Load: Parts are loaded into a barrel attached to a trolly hoist that runs on a track above the process tanks. The loaded barrels then proceed through the various steps using automatic sequencing.
- Electroclean: The loaded barrels are dipped into a cleaning solution and placed on reverse current. By passing an electric current through the parts, gasing occurs on the metal surfaces, which enhances the removal of dirt and oil.
- Rinse: A tank containing tap water serves as an overflow rinse tank to remove dragout. The water use in the rinse tank is regulated by a conductivity controller.
- Pickle: Parts are immersed in a hydrochloric acid (HCl) bath to further remove oil, dirt, and oxide from the metal surfaces.
- Rinse: A tank containing tap water serves to remove residual HCl from the pickled parts. Water use in this tank is regulated by a conductivity controller.
- Dry: The pickled and rinsed parts are blown dry before immersion in the cadmium electroplating tank.

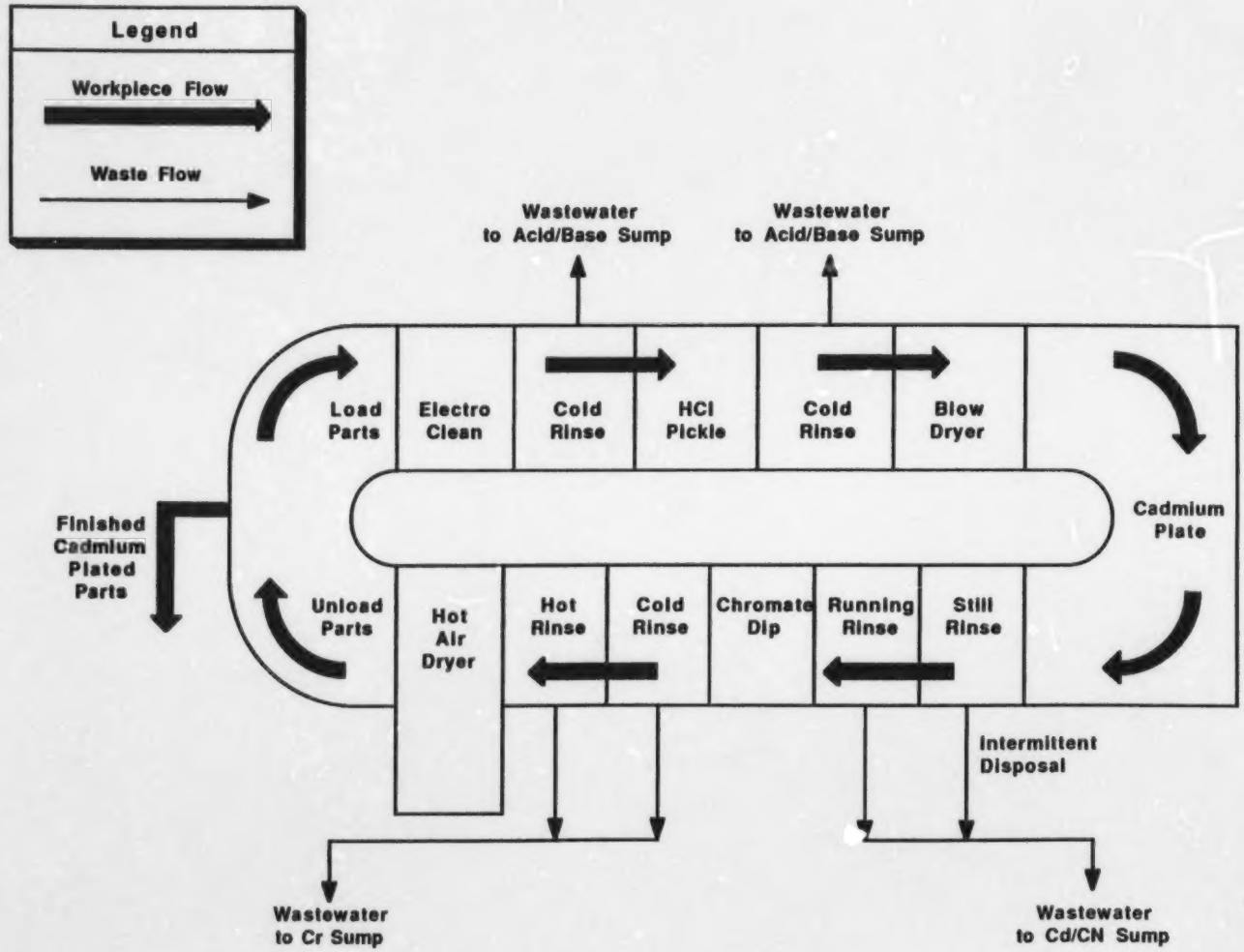

Figure 3. Simplified Schematic: Automatic Barrel Cadmium Plating Line

- Electroplate: The cleaned parts are then immersed into a plating tank containing a cadmium-cyanide electroplating solution. Following the completion of the preset immersion time, the barrel is slowly raised above the tank where air is blown across the basket to reduce the amount of dragout.

- Still Rinse: A tank containing tap water serves as the first rinse tank to remove dragout after plating. No water runs into or out of the tank during daily operation. At the end of the shift, water from this tank is used to replenish water loss from the plating solution caused by evaporation. The remaining water in the tank is discharged to the cyanide sump.

- Rinse: A tank containing tap water serves as a second rinse tank following plating. Water use in the rinse tank is regulated by a conductivity controller.

- Chromating: The plated parts after rinsing are immersed in a solution containing dichromates to form a corrosion protective coating on the plated surfaces. No electric current is needed.

- Rinse: A tank containing tap water serves as a rinse tank to remove dragout after chromating. The barrel remains in the water for approximately 4.5 minutes and is allowed to hang above the rinse tank for 30 seconds before moving to the next tank. Water use is regulated by a conductivity controller.

- Hot Rinse: A tank containing heated tap water serves as the final rinse for the parts. The tank is agitated with air sparging for efficient rinsing. Hot water is used to allow for quick drying of the parts to prevent streaking.

- Dryer: The plated parts pass through a dryer which blows hot air across the barrel to quickly dry the parts.

- Unload: The plated and chromated parts are removed from the barrel.

Four separate barrels are used along the automatic line at the same time. It takes approximately 90 minutes for one barrel to complete the plating circuit.

Wastes discharged from the automatic barrel line include the following:

- Residual still rinse tank water after the cadmium plating tank is filled. This water discharges to the Cd/CN sump.

- Chromium-bearing rinse water from the chromating tank. This waste discharges to the chrome sump as discussed below under the chromium plating line process description.

- Cold water rinse discharges from the electroclean and HCl pickle rinse tanks, respectively.

The manually operated rack line is used for parts that cannot be barrel-plated because of their size or configuration. Figure 4 represents a simplified schematic of the manually operated cadmium-cyanide plating operation. After placing the parts to be plated on racks, the following procedure is followed:

- Pickle: Parts are immersed in an HCl bath to remove oil, dirt, and oxide from the metal surfaces.

- Rinse: There is a cold water rinse using tap water. Water use in this tank is regulated by a conductivity controller.

- Electroclean: The same process is used as in the automatic barrel line.

- Rinse: Another cold water rinse using tap water is undertaken.

- Electroplate: The cleaned parts are then immersed in one of six different plating tanks containing a cadmium-cyanide electroplating solution. One of the plating tanks is located adjacent to the rinse tank following electrocleaning. The other five tanks are lined up adjacent to each other in a parallel line with a walkway between the two lines. The parts may remain in a plating tank anywhere from 5 minutes to an hour depending on the amount of current the operator applies and the thickness of plating required.

- Still Rinse: The first rinse tank following plating is adjacent to the single cadmium-cyanide plating tank. No tap water runs into or out of the tank during daily operation.

- Running Rinse: A tank containing tap water serves as a second rinse tank to further remove dragout. Water use in the rinse tank is regulated by a conductivity controller.

- Chromating: The same process is used as in the automatic barrel line.

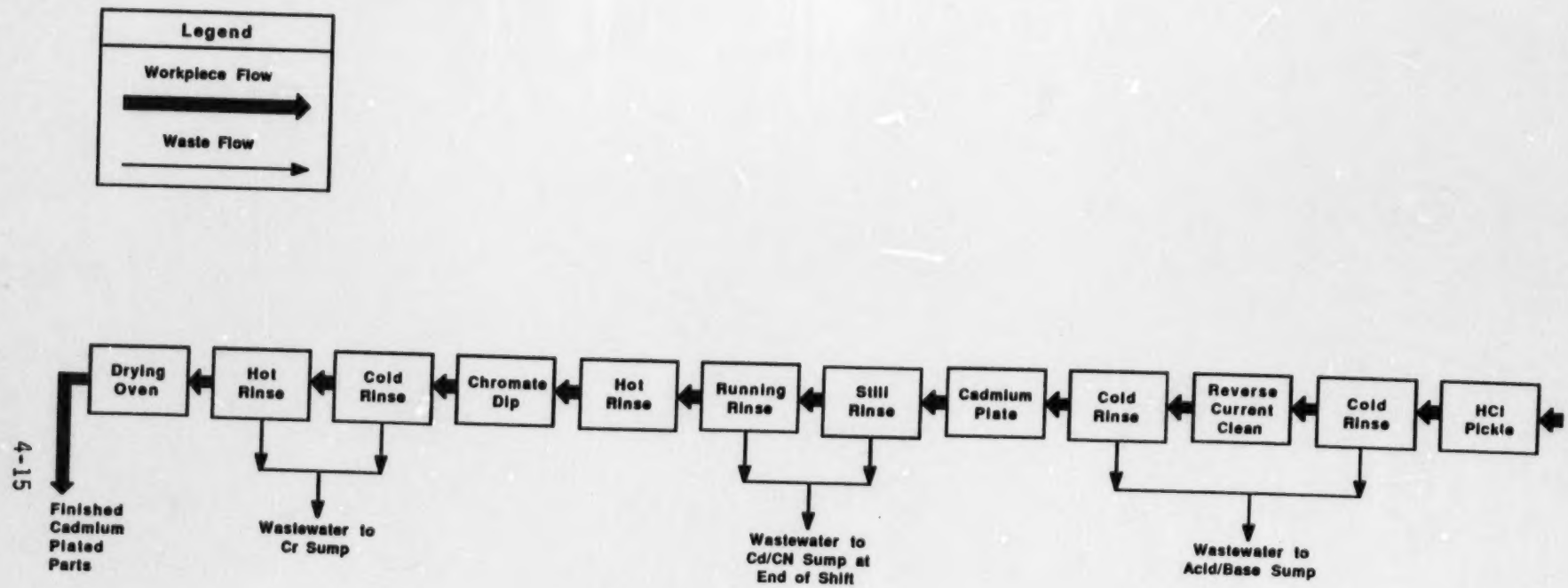

Figure 4. Simplified Schematic: Manual Cadmium Plating Line

- Rinse: A tank containing tap water serves as a rinse tank to remove dragout after chromating. Water use is regulated by a conductivity controller.

- Hot Rinse: A tank containing heated tap water serves as the final rinse for the parts. The tank is agitated using an air sparger for efficient rinsing. Hot water is used to allow for quick drying of the parts to prevent streaking. An air hose helps to dry the parts after the hot water rinse.

- Drying Oven: The plated parts are transferred to an oven to be air dried, completing the plating operation sequence.

Wastes discharged from the manual rack plating line are quite similar to those discharged from the automatic barrel plating line with the waste-waters containing cadmium and cyanide going to the Cd/CN sump in Building 114 and the chromium-bearing wastewaters going to the chromium sump in Building 114.

For both the automatic barrel plating line and the manual rack line, concentrations of the principal chemical constituents of the plating baths are checked periodically and makeup materials are added as required. The cadmium-cyanide plating baths are normally analyzed weekly. The reverse current electrocleaner and HCl pickling tanks are checked monthly and the pickling baths are replaced three to four times per year. The constituent compositions of the principal baths are included in Table 8.

For both lines, plating solution tanks are completely cleaned once a year. The plating solution is pumped to a holding tank and the plating tank is thoroughly cleaned. Because of dragout of contaminant-laden solutions and the continuous filtering of the plating and chromating baths, replacement of these bath solutions is not required.

Hard Chrome Plating

Hard chrome plating at Building 114, while an important operation, has a significantly lower plating volume than are cadmium plating.[1] Chrome plating at Building 114 is a manual operation, often requiring masking of various areas of the parts being plated. Figure 5 represents a simplified schematic of the chromium plating operation. Based on discussions with plant personnel, details of the chromium plating operation follow:

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1 Cadmium plating volume is approximately 100 times the chromium plating volume.

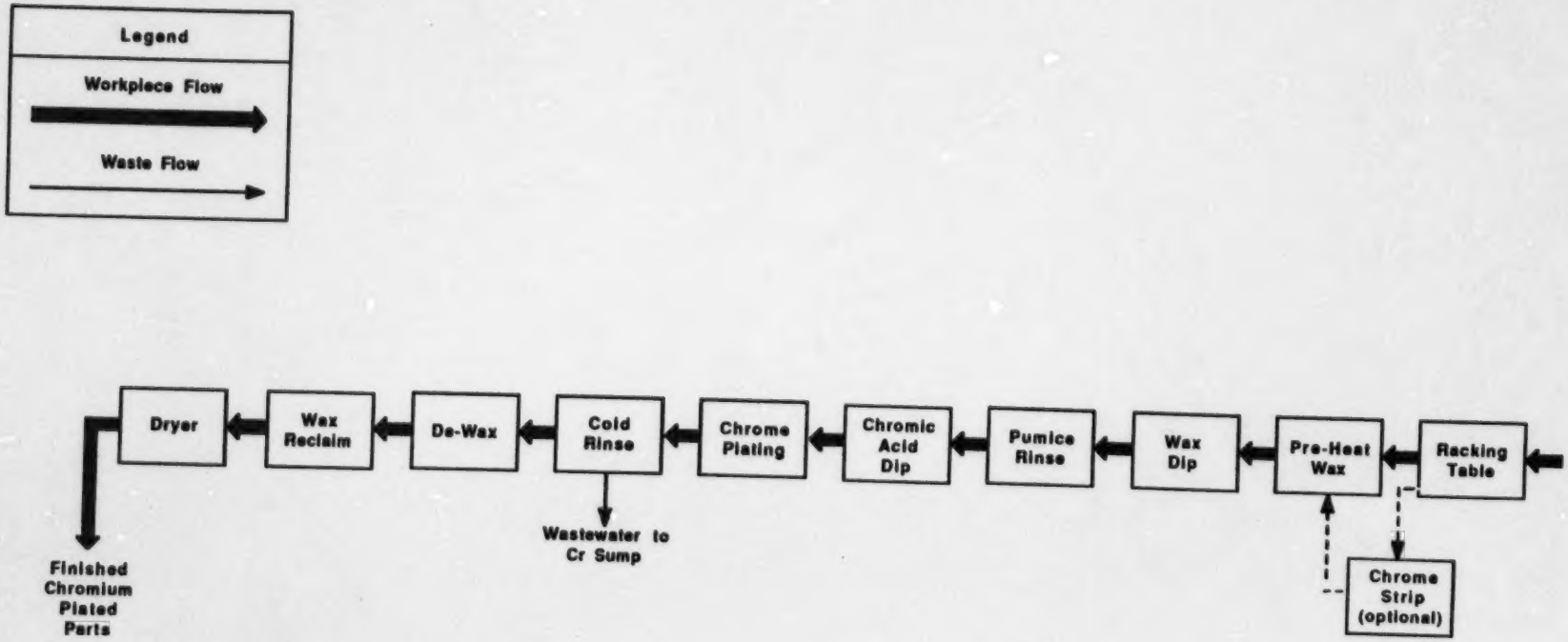

Figure 5. Simplified Schematic: Manual Chromium Plating Line

- Chrome Stripping: When the old metal plate layer must be removed, the parts are dipped into a tank containing a mixed acid stripping solution, with the tank operating as a reverse current stripper. The length of immersion time depends on the thickness of the metal layer to be stripped.

- Masking: Many parts that require hard chrome plating only need a particular section of the piece to be plated. In most cases, the chrome plate is needed to provide a specified hardness and thickness to an engineered piece. To prevent the entire piece from being plated, the area to be plated is covered with a special tape and the piece is submerged in a hot wax. After the wax cools, the tape is removed and the plating process continues. The following tanks are used during the masking operation:

  - Pre-heat wax: The piece is immersed in a heated bath to preheat the surface before applying the wax. Pre-heating results in a better adherence of wax.

  - Wax dip: The piece is submerged in a tank of hot wax to mask the areas not to be plated.

- Pumice Rinse: The area to be plated is scrubbed with a mixture of pumice, a gritty material, and water to help clean and roughen the surface for better adhesion of the plated layer.

- Pickling: The piece is immersed in a chromic acid bath to etch and clean the surface, thus improving adhesion of the plated layer. Chrome-plated parts, found to lack the required thickness of metal, are reimmersed in the chromic acid bath before being placed back into the chrome plating solution.

- Chrome Plating: The cleaned and etched part is immersed into a plating tank containing a chromic acid solution. The operator has eight chrome plating tanks from which to choose. The length of plating time depends on the amount of current applied and the desired thickness.

- Rinse: A tank containing tap water serves as a rinse tank to remove the dragout after plating. Water use in the rinse tank is regulated with a conductivity controller.

- De-wax: A heated bath melts the wax off the parts upon completion of the plating process.

Wastewater discharges from the chromium plating line, including cold water and hot water rinse tank overflows, are sent to the chromium collection sump in Building 114. In addition, chromating tank rinse water wastes from both the automatic barrel cadmium plating line and the manual rack cadmium plating line contain appreciable chromate dragout, requiring these discharges to be sent to the chromium waste sump in Building 114. All chromium waste discharges are sent to the IWTP for hexavalent chromium reduction and trivalent chromium precipitation.

Concentrations of the principal plating bath components are checked periodically and makeup materials are added as required. The chromating baths are normally analyzed weekly, while the chrome plating baths are checked on a monthly basis. The constituent compositions of the principal baths are found in Table 10.

Plating solution tanks are completely cleaned once a year. The plating solution is pumped to a holding tank and the plating tank is thoroughly cleaned. Because of dragout of contaminants-laden solution and the continuous filtering of the plating and chromating baths, replacement of these bath solutions is not required.

WASTE STREAM DESCRIPTION

The only appreciable cadmium/cyanide wastewaters at the DOD installation are the rinse waters used to remove the dragout of plating solutions from electroplating operations and certain parts cleaning operations in Building 114. The major source of chromium wastewater is the rinse waters used to remove the plating solution dragout on plated metal parts in Building 114. Treatment of these wastewaters is described below.

Current data on Building 114 wastewaters and the contaminants of concern (Cd, CN, and Cr) are as follows:[1]

Waste stream	Avg. wastewater flow (gallons per day)	Avg. contaminant concentration (mg/l)		
		Cd	CN	Cr
Cd/CN sump	2,000	21	25	--
Cr sump	34,500	--	--	116

1 Source: Letter from U.S. Army Environmental Hygiene Agency to M. Drabkin, April 30, 1987, "Preliminary Data for the Anniston Army Depot."

CURRENT WASTE MANAGEMENT PROFILE

At the DOD installation, the hazardous wastes described above are treated at the IWTP. The IWTP complex was extensively modified and rebuilt in 1979. This system is designed to treat five separate wastes generated at the DOD installation. These wastes include:

(A) Cadmium/cyanide wastewaters;
(B) Chromium wastewaters;
(C) Phenol- and other organics-bearing wastewaters;
(D) Steam cleaning wastewaters; and
(E) Miscellaneous metal finishing wastewaters.

Treatment of these wastes at the IWTP results in the generation and disposal (in a hazardous waste landfill) of approximately 1,000 tons per year of F006 waste. A schematic of the treatment process in use at the IWTP is shown in Figure 6.

The two wastes of concern in the present WMA, streams (A) and (B), are treated as follows:

(A) Cadmium/cyanide wastewaters. The only known sources of Cd/CN wastewater at the DOD installation originate from plating operations performed in Building 114. Dragout rinses from the plating operations are routed to a sump in the basement of this building from where this waste is pumped to one of four cyanide reactor/holding tanks in Building 506. Cyanide destruction via alkaline chlorination is performed in these holding tanks on a batch basis, with subsequent transfer, chemical coagulation, and precipitation of cadmium as cadmium hydroxide at the IWTP.

The sequence of treatment steps includes the following:

1. Sump pumping from the basement of Building 114 to reactor holding tanks in Building 506.

2. Cyanide destruction at Building 506 using HTH (CaHOCl), on a batch basis, in one of four (2,400-gallon) reactor tanks.[1]

3. Transfer pumping to the IWTP.

4. Waste equalization in a completely mixed 10,000-gallon basin.

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[1] It is currently planned to change the treatment reagent from HTH to liquified chlorine (a system for using the latter reagent is available at the site). Use of chlorine rather than CaHOCl is expected to improve operating efficiency of the alkaline chlorination unit.

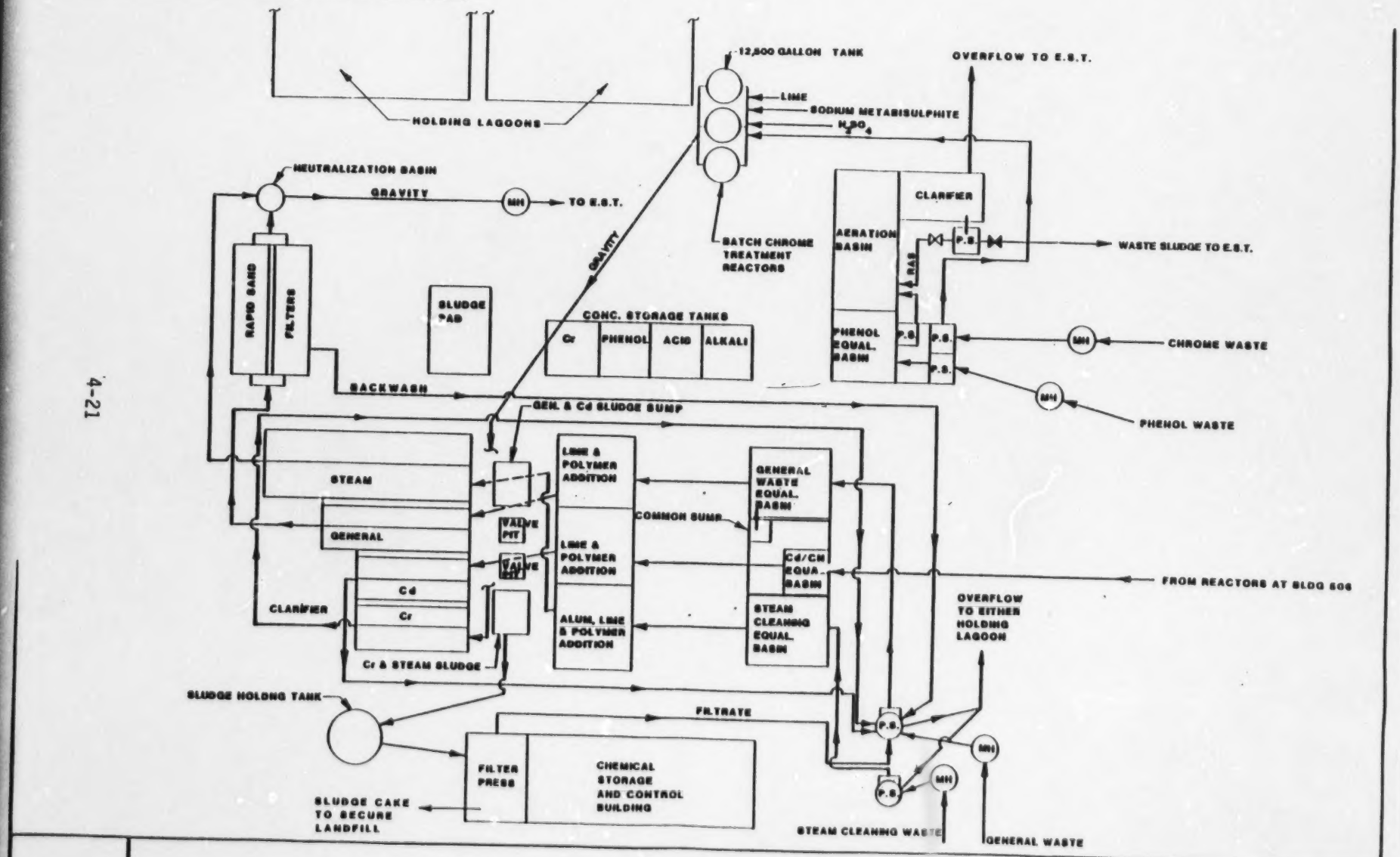

Figure 6. IWTP FLOW SCHEMATIC*

*Source: Malcolm Pirnie, 1986. Initial Report, Industrial Wastewater Minimization Program

5. Transfer pumping to flocculation vessels.

6. Lime addition to effect cadmium precipitation as the hydroxide at a pH of 11 (in one of two Cd clarifiers).

7. Polymer addition and flocculation in two parallel 580-gallon fiberglass tanks.

8. Clarification (first clarifier) within a basin having a capacity of approximately 14,000 gallons and a surface area of 210 ft^2.

9. Flow equalization and pressure filtration.[1]

10. Sulfide addition for additional cadmium precipitation as the sulfide (in the other of the two Cd clarifiers).[1]

11. Clarification (second clarifier) within a basin having a capacity of approximately 14,000 gallons and a surface area of 210 ft^2.[1]

12. Effluent discharged to influent of General Metal Finishing treatment system. This treated waste is ultimately discharged through the DOD installation sanitary treatment system discharge point under a State of Alabama NPDES permit.

13. Collection of the clarifier underflows in a sludge holding tank, followed by dewatering in a plate and frame filter press and discharged to a hazardous waste landfill.

(B) Chromium wastewaters. Chromium wastewater at the DOD installation primarily originates from plating operations in Building 114. Dragout rinses from selected stripping and plating operations are sent to the IWTP for treatment in a series of steps as described below.

1. Sump pumping from the basement of Building 114.

2. Transfer pumping from Building 506 to the IWTP.

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1 This is a recent modification in operating procedures.

3. Influent pumping to one of three reactor tanks (12,500 gallons each) for batch Cr^{+6} reduction to Cr^{+3} followed by lime (or NaOH) and polymer addition for hydroxide precipitation. Batch chromium treatment at the IWTP involves reduction of the hexavalent (+6) ion to the trivalent (+3) form. The first step for Cr^{+6} reduction is to lower the pH 2.5 to 3.0 with sulfuric acid followed by the addition of sodium metabisulfite (reducing agent). Operators are utilizing the color change from yellow to green as an indication that the hexavalent ion has been reduced. Once the hexavalent chromium has been reduced to the trivalent state, lime (or caustic) is added to raise the pH from 8.0 to 9.0, which precipitates chromium (+3) hydroxide from solution.

4. Clarification of the treated wastewater within two parallel clarifiers, each having a capacity of approximately 14,000 gallons and a surface area of 210 ft^2. The chromium hydroxide settles in the two clarifiers with the aid of polymer addition.

5. Effluent discharge to influent of General Metal Finishing treatment system and ultimate discharge through the sanitary treatment system discharge point under a State of Alabama NPDES permit.

6. Collection of the clarifier underflows in a sludge holding tank, followed by dewatering of the sludge in a plate and frame filter press and discharge to a hazardous waste landfill.

POSTULATED WASTE MINIMIZATION OPTIONS

Waste minimization options for reducing or eliminating the generation of listed hazardous waste F006 from electroplating operations in Building 114 were developed by the audit team using the approved EPA hierarchy: source reduction options being more desirable and recycle/reuse options less desirable. Treatment options (not considered as waste minimization) were only explored if no source reduction or recycle/reuse options were available for these wastes. The options considered under these categories are discussed below.

Cadmium/Cyanide Wastes Generated in Building 114

Compliance with the current NPDES permit limit requirements for total cyanide and, to a lesser extent, cadmium, remains the most serious problem in meeting State permit requirements at the DOD installation. The present total cyanide limit is 0.5 mg/l (daily average). During the period from mid-August to mid-November 1986, the IWTP was out of

compliance for total cyanide in more than 50 percent of the daily average values recorded during this period. Of the noncompliance values determined for total cyanide, most appeared to be primarily levels of nonamenable cyanide, i.e., complex cyanides not susceptible to destruction by the alkaline chlorination process in use at the IWTP. In the case of the cadmium compliance level (the NPDES daily average value being 0.1 mg/l) over the same period, the IWTP performance was far better, with only 2 out of 32 measured values of treated effluent cadmium found to be out of compliance. Thus, waste minimization efforts were directed principally at cyanide waste generation (and, to a lesser extent, cadmium waste generation) in order to alleviate the problem of compliance with the IWTF discharge.

(1) Source reduction options. The following source reduction options were considered for reduction and/or elimination of Cd/CN wastes.

Option (a). Minimizing rinse water usage. Both the automatic barrel line and manually operated rack lines employ a cold water rinse immediately following the alkaline electroclean (reverse current cleaning) and HCl pickling of the workpieces. This rinse is done in single tanks, each fed separately with tap water as required. Referring to Figure 1, if the cold rinse water discharge following alkaline reverse current cleaning on the automatic barrel line is piped to the HCl pickling rinse tank, a reduction in rinse water flow would be achieved, neutralization of the acidic rinse water would occur, and wastewater flow to the IWTP would be reduced. There would be a relatively inexpensive piping and pumping cost involved in implementing this option. The same approach can be taken with the Cd/CN rack line (Figure 2), with the cold water rinse following reverse current cleaning being pumped to the cold water rinse tank following the HCl pickling operation. This option does not directly affect cadmium/cyanide waste reduction, but should significantly reduce the amount of waste requiring treatment at the IWTF.

Option (b). Destruction of cyanides by reverse current treatment. The electrolytic destruction of both simple and complex cyanides can occur at the anode of an electrolytic cell using reverse current electrolysis. At a high enough current density and sufficient residence time, cyanides will be oxidized to nitrogen and CO_2 at the anode. It is proposed to use this reaction as a means of destroying waste cyanide in the still rinse tanks immediately following the Cd/CN plating tanks, as well as in the electroclean rinse tank in each of the cadmium plating systems in Building 114 (see Figures 1 and 2). These systems are out of operation during 16 hours each day (plating operations are carried out on the 8:00 to 4:00 shift). During this 16-hour period following shutdown of the cadmium plating lines, the following sequence of steps would occur (as applied to the still rinse tank in the automatic barrel line):

1. Water from the still rinse tank would be used to raise the cadmium plating bath to its desired level.

2. The still rinse tank is then filled with water from the adjacent running rinse tank. The still rinse tank water is kept thoroughly mixed through the use of an air sparger (preferred over a mechanical agitator because of faster circulation of fluid through the tank).

3. Passivated 316 stainless steel cathode plates and 316 stainless steel anode plates are placed along opposite walls of the still rinse tank. An anode to cathode surface area ratio of 1 to 1 is used and the maximum available electrode surface area is employed.

4. Cyanide is destroyed in the still tank by using 8 to 20 amps per square feet of anode. A residence time of up to 16 hours is available for cyanide destruction. A current density as high as possible is used with care taken not to overheat rectifier contacts. If overheating occurs, the amperage is reduced.

5. At the end of 16 hours the rectifier is turned off and the anode and cathode plates are removed. Some cadmium may plate out on the cathodes. The recovered cadmium is stripped from these plates and used during the regular plating operations.

An analogous procedure can be used for the cadmium rack plating line, destroying the cyanide in the still rinse tank in use in that line.

The only additional equipment unavailable to carry out this option is appropriate sets of 316 stainless steel anode and cathode plates. All other equipment, including suitable rectifiers to supply the high current density needed for cyanide destruction is currently on hand at the DOD installation.

The technical feasibility of this option will be ascertained through an experiment to be carried out in the still rinse tank on the automatic barrel line. If this technique proves successful, it is believed that the bulk of the cyanide present in the wastewater discharged to the Cd/CN sump in the sump in Building 114, would be destroyed (including the nonamenable complexed cyanides), with the existing alkaline chlorination system in the IWTP acting as a backup or polishing step to assure that the total cyanide compliance level is achieved.

Option (c). Improve dragout recovery. A drain board positioned between the cadmium plating bath on the manual rack plating line and the adjacent still rinse bath can capture the solution dripping off of a workpiece and channel it back to the plating bath. This is a simple but effective operation and can be incorporated into the present

electroplating process. The drain board can be made of plastic, corrosion-resistant metal, or any other nonreactive materials. The board should be placed slightly sloped toward the plating tank so that drained solution can be routed back to the bath. Once fastened to the tanks, the drain board can serve as a workpiece rest area to allow for adequate drainage in 10 to 30 seconds. The drain board should be cleaned periodically to prevent the accumulation of dirt and the resulting drag-in of contaminants into the cadmium plating bath.

Spray or fog rinsing applied directly over the heated cadmium plating tanks in the manual rack plating line can also substantially reduce the solution dragout rate as well as reduce water consumption. The spray or fog nozzle uses water and air pressure to produce a fine mist. Spraying water droplets directly onto a workpiece is much more efficient than immersing a workpiece into a liquid water bath. A major limitation is that spraying is not effective on oddly shaped parts, since the spray cannot make contact with the entire surface of the object. Sufficiently high surface evaporation rates must exist for those plating tanks using the technique.

(2) Recycle/reuse options. One recycle/reuse option appeared to be available for the Cd/CN wastes generated by the plating operations in Building 114, as described below:

Option (d). Evaporation of Cd/CN plating system wastewater. Plating system wastewaters from both the Cd/CN automatic barrel line and rack line currently total about 2,000 gallons per day at a CN concentration of 25 mg/l. If Option (b) proves unsuccessful in destroying CN in the plating line still rinse tanks, another commercially available option would be evaporation of this wastewater stream in suitable equipment, and returning the concentrated CN solution to the respective Cd plating tanks in the two plating lines. Sufficient evaporation of this waste stream would be required to maintain a water balance in the plating lines, i.e., replacement of the daily water losses from the respective Cd plating tanks. Appropriate amounts of sodium cyanide reagent and cadmium metal would be added to the plating baths as needed to maintain concentration levels in these baths. With installation of this option, the alkaline chlorination unit presently being operated at the IWTP for CN destruction can be shut down, and maintained on standby only, since there would be no CN discharge from Building 114.

Typical systems and costs for evaporation of waste CN plating solution are described in the plating industry trade literature (Williamson and Natof, 1985) as well as in EPA documentation (USEPA 1985).

Implementation of this option is assumed to require evaporation of 90 percent of the generated Cd/CN wastewater in order to recirculate 200 gpd of the concentrated CN solution to the two plating lines (replacing

200 gpd of water that is assumed to be required as daily makeup to the two plating lines). The evaporation system would be located in the basement level of Building 114 near the Cd/CN wastewater collection sump. The evaporator is assumed to be of the vacuum type, with evaporator body and tubes of borosilicate glass for highly corrosive duty. The total installed cost of the evaporation unit (including vacuum evaporator, product and water reuse-water feed tanks, condensate and product return pumps, rinse water filter, all piping, electrical work, and installation), is estimated as $79,000 for a feed rate of 75 gallons per hour, 24 hours per day, 250 days per year. Direct operating costs of this unit are estimated as $27,000 per year including steam, electricity, direct labor, cooling water, and maintenance. The payback period for this unit cannot be estimated since savings in Cd/CN wastewater treatment costs resulting from shutdown of the alkaline chlorination unit, are not available. However, the IWTP would be in compliance with respect to one of its most significant current problems - meeting the NPDES CN discharge limits.

Option (e). Recovery of cadmium from Cd/CN plating wastes. A similar concept employed for cyanide destruction (reverse current electrolysis as described in option (b)), can be employed to recover cadmium from the still rinse tank immediately following the cadmium plating tank in each of the Cd/CN plating lines in Building 114. In this case, cadmium would plate out on the passivated cathode in the tanks at a low current density (2 to 5 amps per square foot of cathode surface). The concentration of cadmium in these tanks, while presently not known, should be the highest of any of the rinse tanks employed in the plating line, since this tank receives the dragout from the cadmium plating tanks. A preliminary estimate of the dragout into this tank in the automatic barrel line is 2.5 lb of cadmium metal per 8-hour shift (SAIC 1986). The recovered cadmium would be recycled to the cadmium plating tanks by inserting the cadmium-coated plates into the plating tanks during the 8 hours of plating operations.

Application of the reverse current electrolytic technique to the still rinse tanks in the two Cd/CN electrolytic lines during the 16-hour downtime period can reduce the cadmium level significantly in the wastewater to the Cd/CN sump in Building 114. Since cyanide destruction has the primary emphasis (option b), the reverse current operation would operate for maximum cadmium plateout for only that portion of the 16-hour period (at low current density) consistent with sufficient time allowed for maximum cyanide destruction. The recovery of the relatively small amount of cadmium metal for its value alone could not be justified because of the cost of labor and power involved. However, the lower overall cadmium level in the Cd/CN wastewater achievable by this method, does reduce the treatment load at the IWTP significantly, thereby lowering treatment costs and ensuring the achievement of the NPDES cadmium compliance level in the effluent from the facility.

Chromium Wastes

(1) Source reduction options. The following source reduction options were considered for reduction and/or elimination of chromium wastes.

Option (f). Improved dragout recovery. A drain board positioned between each chromium plating bath and its adjacent rinse tank can capture the solution dripping off of a workpiece and channel it back to the plating bath. This is a simple but effective operation and can be incorporated into the present electroplating process. The drain board can be made of plastic, corrosion-resistant metal, or any other nonreactive material. The board should be placed slightly sloped toward the plating tank so that drained solution can be routed back to the bath. Once fastened to the tanks, the drain board can serve as a workpiece rest area to allow for adequate drainage in 10 to 30 seconds. The drain board should be cleaned periodically to prevent the accumulation of dirt and the resulting drag-in of contaminants into the chromium plating baths.

Spray or fog rinsing applied directly over the heated chromium plating tanks can also substantially reduce the solution dragout rate as well as reduce water consumption. The spray or fog nozzle uses water and air pressure to produce a fine mist. Spraying water droplets directly onto a workpiece is much more efficient than immersing a workpiece into a liquid water bath. A major limitation is that spraying is not effective on oddly shaped parts, since the spray cannot make contact with the entire surface of the object. Sufficient surface evaporation rates must exist for those plating tanks that will use the technique.

Another method of spray rinsing using a spray chamber in place of a running rinse tank could also be utilized along the chromium plating line. The existing rinse tanks could be fitted with spray nozzle rings. It will be necessary to install one spray nozzle ring for every foot of the tank's depth to provide adequate rinsing of the workpiece. The limitation on oddly-shaped objects still applies to this type of spray rinsing system. Not only will this technique significantly reduce water requirements but it may also be able to generate a more concentrated chromium waste stream that is more susceptible to recycle/recovery techniques than are rinse waters from a running rinse tank.

Option (g). Reduction of chromium loss in ventilation hoods. To reduce the amount of chromium-bearing vapors being sucked up into the ventilation hoods mounted over the heated chrome-plating tanks, the addition of plastic balls to cover the surface of the hot chromate plating solution is recommended. The balls would provide surface areas on which to condense the entrained chrome-bearing mist leaving the hot

plating solution. No data are available on the present chromium losses resulting from entrainment through the hood vents. However, it is believed that using this method could greatly reduce chromium loss, and equipment and maintenance costs would be minimal.

(2) Recycle/reuse options

Option (h). Evaporation of chromium-bearing rinse waters. There is increased interest in the use of evaporation for recovery of chromium-bearing solutions from electroplating wastewaters, since the equipment involved is relatively inexpensive to install and operate, making it a useful tool for minimizing hazardous waste generation. Many atmosphere evaporators are in use for recovery of dragout from hexavalent chromium plating operations.

Application of evaporative recovery to the Cr sump wastewater from Building 114 involves concentrating the chromium content from an average of 116 mg/l to approximately 250 gm/l (about a 2,000 to 1 concentration factor). For the daily average discharge rate of 34,500 gal/day, this involves the evaporation of all but 17 gal/day of water - clearly an uneconomical approach. In addition, the amount of potentially recoverable chromium (as chromic acid) of 33 lb/day at an approximate recoverable value of $50/day, is not economically justifiable for the capital and operating expense involved. This option could become of greater interest if the rinse water volume generated from the Cr plating line is materially reduced by techniques such as those discussed under option (e).

PROJECTED COSTS FOR THE PROPOSED WM OPTIONS

As additional input for evaluating the feasibility of the proposed WM options for the F006 wastes discussed above, projected costs (order of magnitude cost estimates) have been developed, and the results are summarized in Table 12. Two estimates of the payback period may be derived from the installation of the WM options presented in Table 12 and consideration of the present cost of disposal of the hazardous F006 sludge generated by the IWTP:

- An estimate of payback if the proposed source reduction options (a)(1) and (2), (b)(1) and (2), (c)(1) and (2), (f), and (g) and recycle/reuse options (e)(1) and (2) are installed. In this scenario, the total annual cost in 1986 of disposal of the F006 sludge in a hazardous waste landfill was approximately $160,000 ($160/ton). Assuming that the F006 can be suitably delisted by EPA, and the nonhazardous waste resulting from this delisting can be disposed of in a local sanitary landfill at a cost of $40/ton, then the annual savings in disposal costs would be $120,000.

Table 12. Tabulated Projected Costs: WM Options for DOD Installation F006 Wastes[1]

WM option	Waste source	Option type	Option description	Proposed equipment modifications	Estimated installed cost ($)[1]	Estimated annual operating cost ($/yr)
(a)(1)	Cd/CN Barrel Plating Line	Source reduction	Use of electroclean rinse waters as feed to pickling rinse water tank	Water piping and pump	$ 1,000	$ 500
(a)(2)	Cd/CN Manual Plating Line	Source reduction	Use of electroclean rinse waters as feed to pickling rinse water tank	Water piping and pump	1,000	500
(b)(1)	Cd/CN Barrel Plating Line	Source reduction	Destruction of cyanides in still rinse tank	Insertion of SS cathodes and anodes in still rinse tank and operation in a CN destruction mode during plating line downtime	2,000	10,000
(b)(2)	Cd/CN Manual Plating Line	Source reduction	Destruction of cyanides in still rinse tank	Insertion of SS cathodes and anodes in still rinse tank and operation in a CN destruction mode during plating line downtime	2,000	10,000
(c)(1)	Cd/CN Manual Plating Line	Source reduction	Improved dragout recovery; drain board, spray/fog rinsing nozzles over plating tank	Add drain board between Cd plating tank and still rinse tank; install spray/fog rinse	1,500	1,000
(c)(2)	Chromium Manual Plating Line	Source reduction	Improved dragout recovery; drain board, spray/fog rinsing	Add drain board between Cr plating tank and still rinse tank; install spray/fog rinse nozzles over plating tank	1,500	1,000

Table 12. (Continued)

WM option	Waste source	Option type	Option description	Proposed equipment modifications	Estimated installed cost ($)[1]	Estimated annual operating cost ($/yr)
(d)	Both Cd/CN Plating Lines	Recycle/ reuse	Evaporation of Cd/CN rinse water discharge and recycle to both plating lines in appropriate quantities to maintain individual plating bath water balances	Install evaporation unit and auxiliaries in Building 114 basement near Cd/CN waste sump	79,000	27,000
(e)(1)	Cd/CN Barrel Plating Line	Recycle/reuse	Plating out of cadmium in still rinse tank	Insertion of SS cathodes and anodes in still rinse tank to operate in a Cd plating mode during plating line downtime	Use the same equipment as in (b)	20,000
(e)(2)	Cd/CN Manual Plating Line	Recycle/reuse	Plating out of cadmium in still rinse tank	Insertion of SS cathodes and anodes in still rinse tank to operate in a Cd plating mode during plating line downtime	Use the same equipment as in (b)	20,000
(f)	Chromium Manual Plating Line	Source reduction	Improved dragout recovery: replacement of running rinse tank with spray chamber	Install suitable banks of spray nozzles in empty running rinse tank	5,000	2,000
(g)	Chromium Manual Plating line	Source reduction	Reduction of chromium metal losses from hood vents over plating tanks	Add layer of plastic balls on surface of chromium plating tanks	Nil	Nil

[1] Order of magnitude costs (± 50 percent accuracy).

After deducting the incremental operating costs associated with the installed WM options listed above, the payback period would be 14,000/55,000 or approximately 4 months.

- An estimate of the payback if the proposed source reduction options (a)(1) and (2), (c)(1) and (2), (f), and (g) and recycle/reuse options (d) and (e)(1) and (2) are installed. In this scenario, the net annual savings in waste disposal costs would again be $120,000 (assuming that the F006 waste can be suitably delisted). After deducting the incremental operating costs associated with the installed WM options listed above, the payback period would be 89,000/48,000 or 1.9 years.

None of the proposed source reduction or recycle/reuse options would require any additional space requirements (except for option (c) for which adequate space is believed to be available in the basement of Building 114), or extensive modification of existing equipment.

SUMMARY AND DISCUSSION

The F006 waste generated from electroplating processes is a large volume waste product. For the DOD installation, approximately 1,000 tons per year of this waste are sent offsite for disposal in a hazardous waste landfill. In addition to the required disposal of this waste in a hazardous waste landfill, the installation is required to meet low levels of Cd, Cr (total), and CN in effluents covered by an NPDES discharge permit. Currently (and for some time in the past) the DOD installation is having great difficulty in meeting the CN discharge limit. The facility was also having difficulty in meeting the required Cd level in the effluent, but since installation of WM option (e)(1) and (2) in mid-summer of 1987 (see Table 12), this problem appears to have been eliminated.[1]

In summary, the results of the WMA conducted at Building 114 of the DOD installation by the EPA-sponsored audit team, clearly indicated that a number of source reduction and recycle/reuse options may be implemented in Building 114, with a potential payback ranging from 4 months to 1.9 years depending on the choice of options. One recycle/reuse option (recovery of cadmium metal from the still rinse tanks in each of the

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1 Recent NPDES effluent data furnished by the DOD installation appear to prove this point. Prior to the mid-summer installation of WM option (e)(1) and (2), Cd levels during the March-June 1987 period exceeded NPDES levels for over 50 percent of the daily Cd values measured. During the July-September 1987 period, not one exceedance of the permitted Cd levels occurred for the 40 days of measured Cd levels.

plating lines) has already been tested by the facility and found to be feasible, and, as indicated above, has resulted in a significant reduction in Cd levels in the NPDES effluent, assuring compliance with the required effluent level. With respect to a reduction of the CN level in Building 114 Cd/CN wastewater (affecting the CN level in the NPDES discharge), one source reduction option may be available: reverse current destruction of CN in the still rinse tank during the plating line daily downtime period. This option is currently being evaluated at the facility. A recycle/reuse option, concentration of Cd/CN plating rinse water and return to the plating tanks, is commercially available and may represent the solution to the NPDES CN compliance problem if the source reduction option proves infeasible. A number of source reduction options for reducing Cr levels in that plating line rinse water waste, are also available to reduce Cr levels in the F006 sludge, as well as to reduce the total amount of this sludge.

SECTION 5

LISTED WASTES F002 and F004 - WMA CASE STUDY

The focus of this case study is to propose ways to reduce or eliminate the generation of listed wastes F002 and F004. These wastes are defined in 40 CFR 261.32 as follows:

F002: Spent halogenated solvents including methylene chloride; and

F004: Spent nonhalogenated solvents including cresols and cresylic acids.

A DOD installation that includes a facility generating these solvent wastes from paint stripping operations, was chosen as the host site.

FACILITY DESCRIPTION

(See Section 4)

EQUIPMENT LAYOUT DESCRIPTION

Solvent stripping operations for removal of epoxy paints (and to a lesser extent) polyurethane paints from various tank parts rehabilitated at the DOD installation, are carried out principally in Buildings 129, 130, and 409. Most of the large tank components are stripped by dry abrasives, with the more intricate and delicate components being dipped in stripping solvents. Wastewaters carrying solvent dragout from the paint stripping operations are routed to the IWTP for treatment. Figures 7, 8, and 9 present schematics of the production area layouts and wastewater discharge points in these buildings, respectively. Table 13 summarizes the tank capacity for organic solvents in use for paint stripping operations in Buildings 129, 130, and 409.

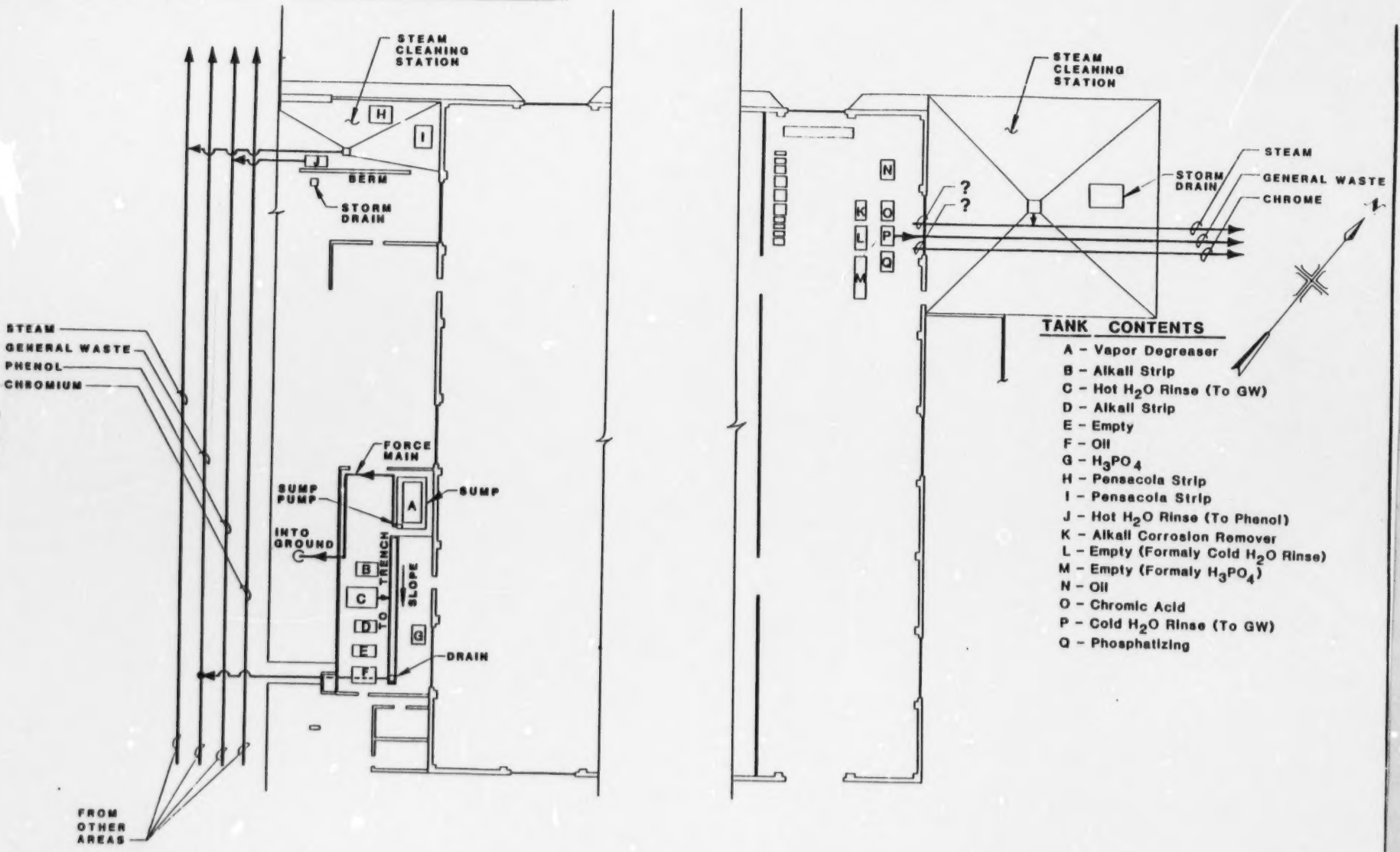

Figure 7. **PRODUCTION AREA LAYOUT AND WASTEWATER DISCHARGE SCHEMATIC FOR BUILDING 129***

*Source: Malcolm Pirnie, 1986. Initial Report, Industrial Wastewater Minimization Program

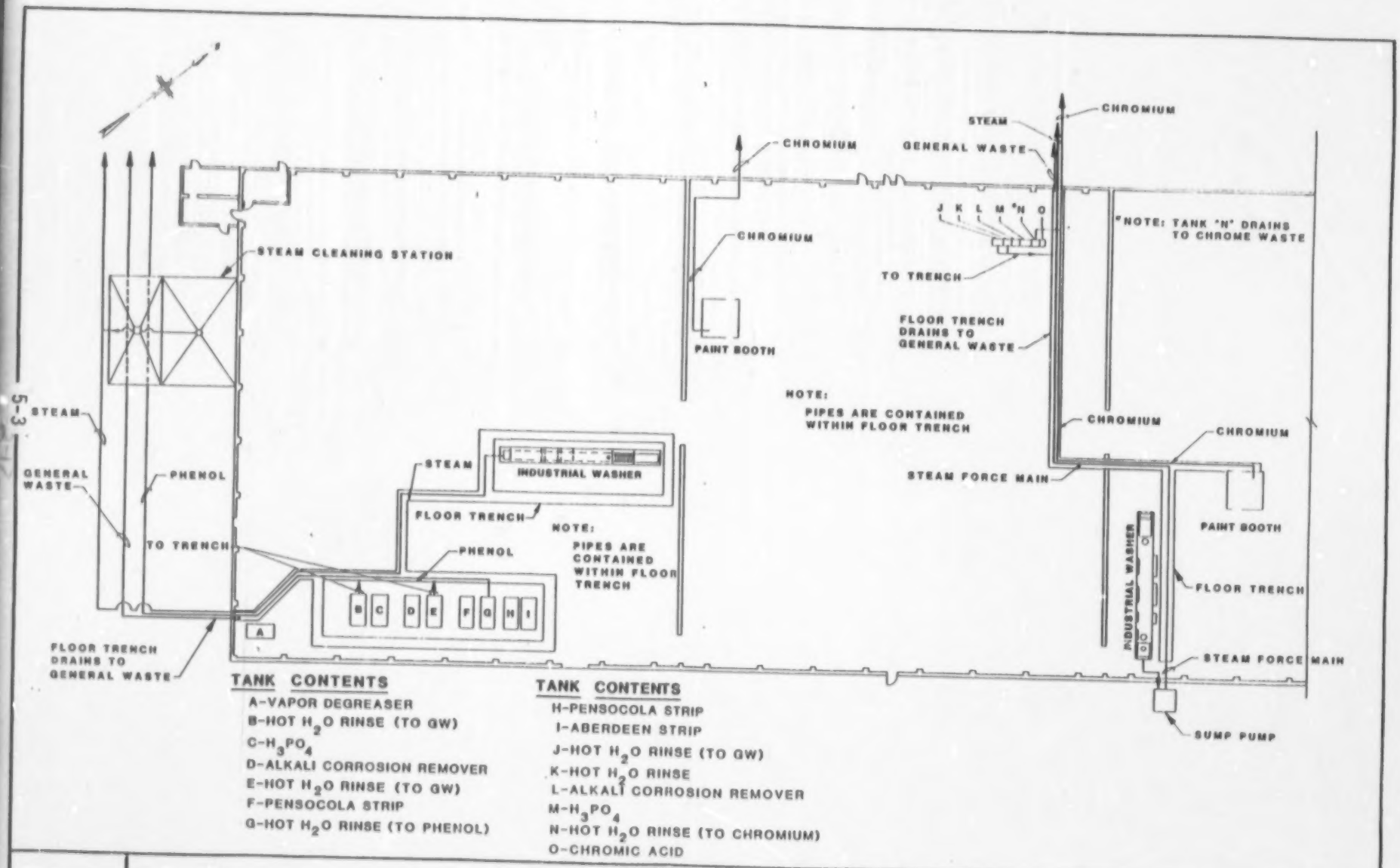

Figure 8. **PRODUCTION AREA LAYOUT AND WASTEWATER DISCHARGE SCHEMATIC FOR BUILDING 130***

*Source: Malcolm Pirnie, 1986. Initial Report, Industrial Wastewater Minimizaiton Program

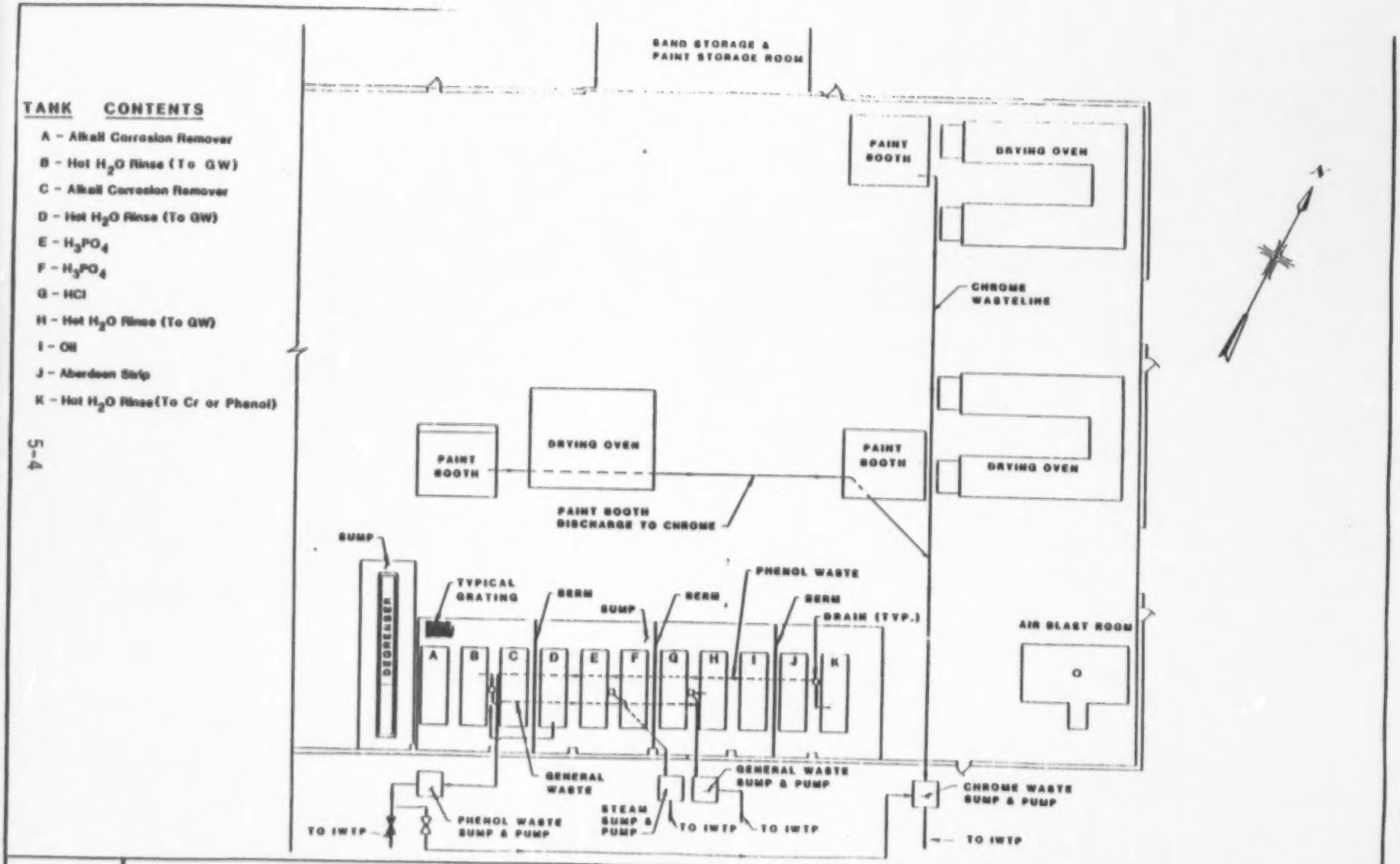

Figure 9. PRODUCTION AREA LAYOUT AND WASTEWATER DISCHARGE SCHEMATIC FOR BUILDING 409*

*Source: Malcolm Pirnie, 1986. Initial Report, Industrial Wastewater Minimization Program

Table 13. Paint Stripping Solvent Handling Capacity at the DOD Installation[1]

Building No.	Tank No.[2]	Tank capacity (gallons)	Trade name of paint solvent formulation[3]
129 West	1	1,200	Pensacola
	2	1,100	Pensacola[4]
130	1	2,150	B and B
	2	1,558	Aberdeen
	3	1,558	Aberdeen
409	1	3,000	Aberdeen
	Total	10,566	

[1] Source: DOD installation in-house data.

[2] These numbers are arbitrary designations assigned to these units and do not correspond to the actual site designations.

[3] Formulation compositions discussed in Process Description portion of Section 5.

[4] This formulation is currently replaced with an experimental paint solvent formulation intended to provide better stripping performance on urethane painted tank parts.

PROCESS DESCRIPTION

When refurbishing tank vehicles at the DOD installation, an extensive amount of paint stripping must be performed on each vehicle. Paint formulations for years have largely been comprised of epoxies and enamels, although developmental work and successful testing of new product coatings by the Army has recently required the DOD installation to begin to use a new urethane coating system. This new urethane finish is more resistant to conventional stripping formulations presently used at this installation.

Discussions with plant personnel indicated that a significant percentage of the parts associated with tank refurbishing are stripped with dry abrasives, such as steel shot and other granulated materials. However, there are some components whose use, geometry, or product specifications require that they be stripped by other than dry abrasives, such as by chemical strippers in a liquid bath. These chemical formulations vary from alkali to acidic solutions, with bath temperatures ranging from hot to ambient. The organic stripping solutions are all used at ambient temperature. The majority of the chemical (paint) stripping formulations are acidic in nature and contain various organic chemical combinations depending upon the manufacturer selected. Table 14 summarizes the organic chemicals used and the ranges of concentration in the various formulations employed for paint stripping.

Table 14. Chemical Constituents and Their Ranges of Concentrations in the Paint Stripping Solvents Used at the DOD Installation

Chemical	Range of percentages used in the various stripping formulations
Methylene chloride	40 to 88%
Phenol	5 to 25%
Cresol	0 to 5%
Formic acid	5 to 15%
Methanol	5 to 20%

A summary of the different types of paint stripping solvents used in each of the production areas, as well as the ingredients in each solvent, is given in Table 15.

Table 15. Ingredients and Usage Locations of Paint Stripping Solvents Used at the DOD Installation

Building location	Paint solvent trade name[1]*	Principal ingredients	Comments
129 West	Pensacola Strip (Type I)	Methylene chloride Cresol Oleic acid Phenol	Used on Al, Mg, and steel parts
130	B and B Strip	Methylene chloride Cresol	Used on Al and steel parts
	Aberdeen Strip	Methylene chloride Cresol Formic acid	Al parts only
409	Aberdeen Strip	Methylene Chloride Cresol Formic acid	Al parts only

[1] The percentage of each of these ingredients will vary, depending upon the paint solvent formulator selected. In addition, the solvents may also contain any combination of the following: benzene, alcohols, EDTA, solvents, naptha, and chromates.

Operation of the paint stripping solvent tanks consists of suspending baskets of the painted tank parts to be stripped in the appropriate solvent tank, followed by immersion in a hot water rinse in an adjacent tank. Details of the solvent paint stripping operations at the various locations in the DOD installation are as follows:

- Building 129 West has two tanks that contain the phenolic-based Pensacola stripping formulation. Paint stripping within this area is normally performed on aluminum transmission cases as well as on magnesium parts. Following the stripping operation, most of the dragout is manually sprayed and hosed off from the workpiece before it receives a hot rinse in an adjacent tank. The rinse water from the manual spray rinsing step flows into a floor drain and is directed to the steam cleaning system. The overflow from the hot rinse tank was recently disconnected from the steam cleaning system and routed to the phenol waste collection system (see Figure 7 for the waste discharge arrangements).

- Building 130 currently has three tanks containing concentrated stripping solutions, two of which are Aberdeen Strip (nonphenolic-based); the third tank contains B and B strip, which is a cresol-based paint stripper. Parts which have been soaked in any one of these three tanks are rinsed in one common hot water rinse tank which is connected to the phenol waste collection system (see Figure 8 for waste discharge arrangements).

- Building 409 has one stripping tank that contains a nonphenolic-based compound (Aberdeen Strip). This tank is used exclusively for Al parts. An intermediate step or manual spray rinse (such as previously described for operations in Bldg. 129) is not utilized within this process. An adjacent rinse tank containing hot water with air agitation is the only means for dragout rinsing from each workpiece withdrawn from this tank. (See Figure 9 for the sump and piping arrangements at Building 409.)

Paint stripping of steel parts is also performed in either of two hot alkali tanks, with an adjacent hot water rinse tank.

WASTE STREAM DESCRIPTION

Listed wastes F002 and F004, which contain varying percentages of the constituents methylene chloride, phenol, cresol, and formic acid (the latter an Appendix VIII listed constituent), are generated principally from two sources:

(1) Rinse waters used to remove the dragout of chemical stripping formulations from paint stripping tanks in Buildings 129, 130, and 409.

(2) Periodic discharges of the spent paint stripping solvents and associated paint sludges from their respective tanks resulting from excessive buildup of paint sludges in these tanks. This usually occurs twice a year during plant turnaround times (July and December).

Treatment of wastes in item (1) is accomplished in the IWTP as described below. The waste discharges in Item (2) are currently sent offsite for disposal in hazardous waste landfills.

Data on the flow and composition of wastes under item (1) are limited. The available data are presented below:[1]

Building No.	Avg. wastewater flow (gallons per day)	Avg. phenol concentration (mg/l)
129	Data not available	Data not available
130	3,000 gallons/week[2]	225
409	964	92

The volume of spent solvents discharged under item (2) can be estimated from data in Table 2. The composition of these wastes at the time of discharge is variable, but the basic constituents and ranges of concentration to be expected are shown in Tables 13 and 14.

CURRENT WASTE MANAGEMENT PROFILE

At the DOD installation, the hazardous spent solvent wastes discussed above are currently managed, as described in the following section.

Spent Solvent-Bearing Wastewater Treatment at the IWTP

The IWTP complex at the DOD installation is described in Section 4. Among the five wastewater streams treated at this facility are phenolic- and other organics-bearing wastewaters. These wastewaters are treated as shown below.

Wastewaters containing phenolic and other organic compounds are presently treated in a separate biological pretreatment facility in the IWTP. The treatment steps include:

1. Influent pumping to the biological treatment system.
2. Aerated flow equalization in a 22,500-gallon basin.
3. Transfer pumping to the aeration basin.
4. Activated sludge treatment, with aeration basin capacity of approximately 79,000 gallons.

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1 Source: Letter from U.S. Army Environmental Hygiene Agency to M. Drabkin, April 30, 1987, "Preliminary Data for the Anniston Army Depot."

2 This is a batch dump once a week. No total continuous flow data are available for the phenol-bearing wastewater stream discharged to the IWTP.

5. Final clarification within one clarifier, having a capacity of approximately 4,000 gallons.

6. Sludge from the clarifier recycled to the aeration basin.

7. Discharge of the clarifier overflow to the DOD installation sanitary treatment system and final effluent discharge under a State of Alabama NPDES permit.

8. Discharge of waste-activated sludge to the DOD installation sanitary treatment system.

Disposal of Spent Solvents (F002 and F004 Wastes)

The bulk discharge of spent phenolic and nonphenolic organic paint stripping solvents is accomplished during July and December of each year. The various spent solvents in each tank in Buildings 129, 130, and 409 are vacuumed into tank trucks and sent offsite for disposal as hazardous waste. Paint stripping sludges, which are drawn off the bottom of each of these tanks, are placed in 55-gallon drums and sent to the hazardous waste landfill. In 1986, about sixty 55-gallon drums of paint stripping sludge were shipped to this landfill. Based on two changes of solvent per year in each paint stripping solvent tank and the data in Table 13, it is estimated that approximately 21,000 gallons per year of spent paint stripping solvent are discarded at the DOD installation. This material is disposed of through a centralized DOD waste disposal agency at a cost of $5/gallon (as of July 1987). Thus, the annual disposal cost for this waste is currently estimated as $105,000 per year.

POSTULATED WASTE MINIMIZATION OPTIONS

Waste minimization options for reducing or eliminating the generation of listed hazardous wastes F002 and F004 from paint stripping operations in Buildings 129, 130, and 409, were developed under the approved EPA hierarchy: source reduction options being more desirable and recycle/reuse options less desirable. Treatment options (not considered as waste minimization) were only considered if no source reduction or recycle/reuse options were available for these wastes. The options considered under these categories are discussed below.

Wastewaters Generated in Buildings 129, 130, and 409

Source reduction options

Option (1). Reduction of dragout. In the operation of the solvent paint stripping process for miscellaneous tank parts in Buildings 129, 130, and 409, the baskets of stripped parts are suspended over the

solvent tanks for sufficient time to allow excess solvent to drip off the parts back into the tanks. However, there is an unavoidable dragout of solvent when odd-shaped parts are placed in the baskets (causing hang-up of liquid between and in the interstices of these parts), as well as that caused by solvent retention resulting from surface tension effects. A deliberate effort could be made to minimize this situation by:

- Loading the baskets less full of parts to be stripped;
- Stacking the parts appropriately to allow space between them for the solvent to escape; and
- Placing parts containing hollows, crevices, etc., in an inverted position to allow for more complete drainage.

Recycle/Reuse Options

Option (2). Recovery of solvent. With the dissolved organic levels in the rinse water waste only in the 250 mg/l range (as phenol) and the organic components being mixed in varying proportions in the waste, no recovery process, e.g., solvent extraction or carbon adsorption, appears either technically or economically feasible for this purpose.

Treatment Options

Option (3). Modification of phenolic wastewater treatment system. While treatment is not considered a waste minimization option, the present treatment system for the phenol-bearing wastewater was studied to determine if possibilities existed to improve the operation. From phenol waste stream treatment data supplied for the period from August to November 1986, it was noted that excursions above the Alabama discharge limit (approximately 25 percent of the reported data were above the daily average limit of 0.2 mg/l for phenol in the treated wastewater), for phenol occurred primarily during the first part of the week (Monday through Wednesday). This could be due to a large fluctuation in the phenol concentration in the influent to the biological treatment system caused by a large batch dump of this wastewater from Building 130 (a 3,000-gallon dump at the beginning of the work week). This discharge would significantly affect the phenol concentration of the feed to the biological treatment system, since this dump is blended with relatively small flows (under 1,000 gallons per day each) from the other two sources of phenol-bearing wastewater discharged to the IWTP. Large fluctuations in the phenol feed concentration appear to affect the biological system performance, since the system does not fully recover and perform properly until the latter part of the week.

A proposed solution to this problem would be to install another 3,000 gallon storage tank in Building 130, and discharge the waste from the existing 3,000-gallon tank on a uniform basis, i.e., 600 gallons per day, while the second tank is accumulating waste rinse waters from the solvent rinsing operations.

Solvent Waste Generated in Buildings 129, 130, and 409

Source reduction options

The following source reduction options were considered to reduce and/or eliminate solvent wastes generated in Buildings 129, 130, and 409.

Option (4). Continuous solvent cleanup using centrifugation. The various methylene chloride-based solvents in use in these buildings for stripping paint from miscellaneous tank parts, are currently replaced twice a year because of paint sludge buildup in the solvent. The paint sludge ranges from gelatinous small particle size material to discrete particles of paint averaging one-quarter inch in size. If this material can be continuously removed from the solvent as it is formed by the stripping action of the latter, then the requirement for replacement of the solvent on a semiannual basis may be eliminated, and the only solvent replacement costs would be due to normal evaporation losses, dragout, and losses resulting from entrainment in the sludge.

One method chosen for consideration as a continuous sludge removal mechanism is the use of a solid bowl centrifuge. Each of the six tanks in the three buildings having solvent paint stripping operations would be equipped with a batch solid bowl centrifuge, feed pump, and a removable bowl for manual sludge solids cleanout. On a daily basis, each centrifuge would collect about 1 to 2 gallons of sludge solids.[1] At the end of the shift, the bowl containing the accumulated solids would be removed and replaced with a spare bowl. The solids would be scraped out of the bowl and collected in a sludge solids drum. The drums would then be accumulated over a 90-day period and shipped to a hazardous waste landfill. Approximately 50 drums of this material would be generated per year.

Using this WM technique, it is believed that the waste stream of approximately 21,000 gallons per year of paint stripping solvent presently disposed of as hazardous waste could be eliminated. However, in evaluating the economic feasibility of this option, it is assumed that complete replacement of paint stripping solvents would be required once a year.

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1 This is considered to be a conservative estimate based on six 55-gallon drums of sludge collected every 6 months from each tank when the paint solvent tanks are emptied.

A sample of sludge collected from the bottom of an Aberdeen strip tank in Building 409, is currently being evaluated by a centrifuge vendor to determine the required operating parameters for this equipment.[1]

Option (5). Continuous solvent cleanup using filtration. An alternative technique for solvent cleanup, assuming that centrifugation is not effective for this purpose, would be the use of continuous filtration. In this case, a dual or two-stage unit would be used: the first stage consisting of a plastic bag filter to remove larger pieces of paint sludge (down to 25 microns in size) and a second stage consisting of a porous metal cartridge filter to remove sludge particles down to one micron in size. Each of these filter units would be housed in a "duplex" housing equipped with two of the filter media. This installation would permit continuous filtration to occur should a bag or cartridge element become prematurely plugged. Normal filtration operation is envisioned as requiring a switchover to a fresh bag and cartridge once per day at the end of the shift. The filter bag and cartridge (loaded with paint sludge) would be collected in 55-gallon drums and shipped to a hazardous waste landfill at appropriate intervals. It is believed that use of this technique would maintain the solvent in a continuously clean condition, thus eliminating the need for disposal of approximately 21,000 gallons per year of this material. Again, however, when evaluating the economic feasibility of this option, it is assumed that complete replacement of paint stripping solvents would be required once a year.

Recycle/reuse options.

No recycle/reuse options were developed for the paint stripping solvents in use in Buildings 129, 130, and 409.

PROJECTED COSTS AND SITE AREA REQUIREMENTS FOR THE PROPOSED WM OPTIONS

As additional input for evaluating the overall feasibility of the proposed WM options discussed above, projected costs (order of magnitude cost estimates) and any modifications to the plant locations where these options would be implemented, have been developed, and the results are summarized in Table 16 for F002 and F004-related options.

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1 A preliminary communication from the centrifuge vendor indicates that centrifugation can successfully separate the paint sludge from the solvent, producing a clear solvent product.

Table 16. Tabulated Projected Costs and Required Site Modifications: WM Options for DOD Installation F002 and F004 Wastes

WM Option[1]	Waste source	Option description	Proposed equipment modifications	Estimated installed cost ($)	Estimated annual direct operating cost[2] ($/yr)	Required site modifications	Payback period (years)
(1)	Dragout from painted parts stripping tanks resulting in waste rinse waters	Modification of paint stripping operations to minimize dragout	----------	---	---	----------	-
(3)	Dragout from painted parts stripping tanks resulting in waste rinse waters	Modification of discharge to biological treatment plant to avoid wide flow fluctuations	Install second 3,000-gallon tank in Bldg. 130 to hold week's rinse water accumulation while full 3,000-gallon tank is discharging wastewater at metered rate.	8,000	---	Floor space is believed to be available for this tank; no major existing equipment relocation would be required.	-
(4)	Waste paint stripping solvent disposal	Continuous removal of paint sludge from solvent (using a solid bowl centrifuge) to avoid necessity of solvent disposal when sludge content gets too high	Add a pump and solid bowl centrifuge to each of the six paint stripping solvent tanks; unit operates at about 5 gpm flow rate.	50,000	5,000	Adequate floor space is available in front of each of these stripping tanks to permit installation without major existing equipment relocation.	0.5
(5)	Waste paint stripping solvent disposal	Continuous removal of paint sludge from solvent (using a two-stage filtration unit) to avoid necessity of solvent disposal when sludge content gets too high	Add a pump and two-stage filtration unit (first stage is basket type filter for large pieces and second stage is a porous metal filtration cartridge for micron-size particles.	60,000	9,000	Adequate floor space is available in front of each of these stripping tanks to permit installation without major existing equipment relocation.	0.67

[1] All options shown are source reduction options except for (3), which is a treatment option, i.e., not a WM option.

[2] Other than the cost of replacing spent paint stripping solvent, which is estimated separately.

There would be no cost involved in implementing the proposed source reduction options for reducing phenol-bearing wastewater generation. The alternative option which is revamped handling of phenol-bearing wastewater (not a WM option) in order to overcome present operating difficulties of consistently meeting the required treated effluent phenol levels, would cost about $8,000 to install. There would be no incremental operating costs, and adequate space is believed to be available in Building 130 to accommodate the equipment involved.

For those WM options aimed at reducing or eliminating the source of F002 and F004 solvent wastes, payback periods have been estimated for two alternatives; these alternatives are presented below:

(a) The use of solid bowl centrifuges installed at each of the six paint stripping tanks for continuously removing paint sludge. This would result in an annual savings in purchased solvent cost of $48,000 if annual replacement of solvent was required instead of the present semiannual replacement. By discarding spent paint stripping solvent annually instead of semiannually, annual hazardous waste disposal costs would be cut in half, i.e., about $53,000 instead of the currently estimated $105,000. In this scenario, the estimated payback period would be 50,000/96,000, or approximately 6 months.

(b) Should centrifugation not be an appropriate treatment for paint stripping solvent cleanup, the other alternative available is the use of two-stage cartridge/bag filtration equipment installed at each of the six solvent tanks for continuously removing paint sludge. If solvent were replaced annually instead of semiannually, the annual savings in purchased solvent cost would be $45,000. In this scenario, using $53,000 per year as the net savings in waste paint stripping solvent disposal, the estimated payback period would be 60,000/89,000, or approximately 8 months.

Since the payback period for these two proposed WM options is essentially the same, choice of the appropriate option would depend on their technical feasibility. Assuming that both options are technically feasible, the audit team believes that the continuous centrifugation mode of paint stripping solvent cleanup is the preferred option from the standpoint of ease of operation. Over the long term, however, the lower maintenance cost of the filtration option could be the deciding factor in the choice of one of these WM techniques.

SUMMARY AND DISCUSSION

The DOD installation currently generates F002 and F004 spent paint stripping solvent wastes in three main areas: Buildings 129, 130, and 409. These hazardous waste materials are discharged as both contaminated rinse waters from the paint stripping operations performed on tank parts and as spent halogenated solvent formulations from the stripping tanks themselves. The IWTP is presently able to handle treatment of the wastewaters so that they can be discharged under an NPDES permit (based on meeting a phenol level in the treated wastewater). Occasionally, sudden surges in wastewater discharges from Building 130 will cause difficulties in the ability of the IWTP to meet the phenol level in the treated discharge. The spent paint stripping solvents themselves are presently not reclaimed, but are periodically discharged (along with paint sludges) as hazardous wastes for disposal.

In summary, the results of the WMA conducted at Buildings 129, 130, and 409 of the DOD installation by the EPA-sponsored audit team, clearly indicated that reduction of the organic waste treatment load at the IWTP was available through a source reduction option (minimization of paint stripping solvent dragout by revised operating procedures) and a non-WM option (revamped method of discharge of phenols-bearing wastewaters from Building 130). Additionally, two source reduction options appeared to be available to significantly reduce waste F002 and F004 solvent discharges from these three locations, through the use of continuous centrifugation or filtration operations (to continuously remove paint sludge generated by the stripped tank parts) at the six paint stripping locations in these buildings. Specifically, paint stripping solvent replacement can be conducted on an annual basis instead of a semiannual basis, thus halving the annual F002 and F004 waste disposal cost. Using a continuous centrifuge process, a preliminary estimate of the payback period would be approximately 6 months. If a continuous filtration process were used, a prelminary estimate of the payback period would be about 8 months. Preliminary testing by a centrifuge vendor of a sample of paint sludge-loaded stripping solvent indicates that this process is technically feasible.

SECTION 6

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